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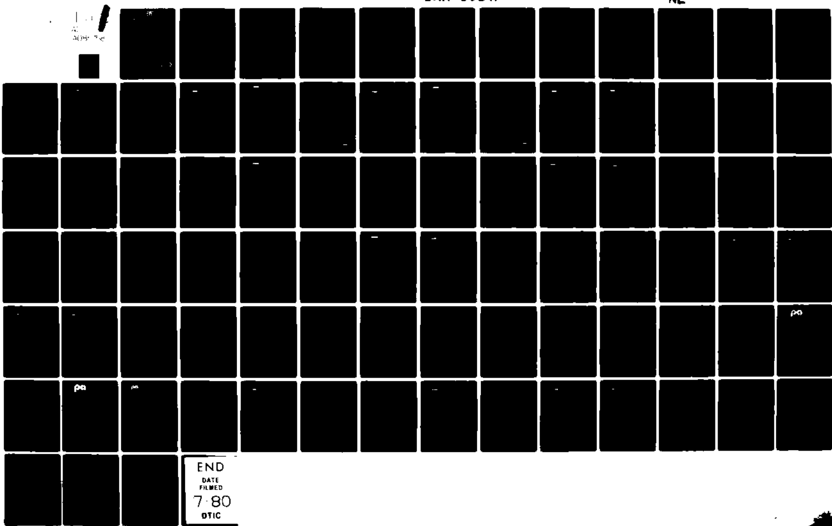

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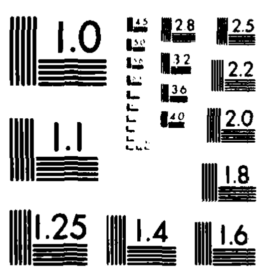

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SUMMARY OF STRUCTURAL EVALUATION AND DESIGN SUPPORT FOR THE UNDERGROUND NUCLEAR TEST PROGRAM

Engineering Decision Analysis Company, Inc.
2400 Michelson Drive
Irvine, California 92715

1 July 1979

Final Report for Period June 1978—July 1979

CONTRACT No. DNA 001-78-C-0281

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

DIABLO HAWK	Large Cavity Events	High Speed Camera
MINERS IRON	Containment Structures	Tunnel Environment
HURON KING	Overburden Plugs	TEMS
HYBLA GOLD	Shock Mounting	Ground Shock

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

During the period from June 1978 through July 1979, Engineering Decision Analysis Company, Inc., (EDAC) was under contract to provide structural evaluation and design support for the underground nuclear test program. This effort including the design and evaluation of containment structures for the DIABLO HAWK, MINERS IRON and HURON KING events, design and evaluation of shock mounting systems, data reduction and evaluation of results for the DIABLO HAWK and HYBLA GOLD Tunnel Environment Monitor System (TEMS) and

20. ABSTRACT (Continued)

DIABLO HAWK High Speed Camera experiments and evaluations in support of future large cavity events. This report in a single volume, provides documentation of various design and analysis tasks accomplished under this contract.

PREFACE

Over the time period between June 1978 and July 1979, Engineering Decision Analysis Company, Inc. (EDAC) has been under contract to Defense Nuclear Agency to provide structural evaluation and design support for the underground nuclear testing program. This report is presented to document, in a single volume, the results of the design and analysis tasks conducted under this contract.

EDAC would like to acknowledge the valuable assistance of DNA personnel who have provided guidance to this effort and have contributed data and information toward the preparation of the various evaluation reports. Specifically, EDAC wishes to thank Mr. Joseph W. LaComb who functioned as the Contracting Officer's Representative (COR) on this contract. Also, EDAC wishes to thank Captain James West, Captain Larry D. Willis and Mr. Robert Shirky of DNA; Mr. Frank Fuhriman, Mr. Kenneth Farrimond, Mr. A. C. Hollins and Mr. Arthur Patton of Holmes and Narver; Mr. Donald Farmer of EG&G; and Mr. Neal Speer of BFEC.

Conversion factors for U.S. customary to metric (SI) units of measurement.

To Convert From	To	Multiply By
angstrom	meters (m)	1.000 000 X E -10
atmosphere (normal)	kilo pascal (kPa)	1.013 25 X E +2
bar	kilo pascal (kPa)	1.000 000 X E +2
barn	meter^2 (m^2)	1.000 000 X E -28
British thermal unit (thermochemical)	joule (J)	1.054 350 X E +3
calorie (thermochemical)	joule (J)	4.184 000
cal (thermochemical)/cm^2	mega joule/m^2 (MJ/m^2)	4.184 000 X E -2
curie	*giga becquerel (GBq)	3.700 000 X E +1
degree (angle)	radian (rad)	1.745 329 X E -2
degree Fahrenheit	degree kelvin (K)	$t_K = (t°f + 459.67)/1.8$
electron volt	joule (J)	1.602 19 X E -19
erg	joule (J)	1.000 000 X E -7
erg/second	watt (W)	1.000 000 X E -7
foot	meter (m)	3.048 000 X E -1
foot-pound-force	joule (J)	1.355 818
gallon (U.S. liquid)	meter^3 (m^3)	3.785 412 X E -3
inch	meter (m)	2.540 000 X E -2
jerk	joule (J)	1.000 000 X E +9
joule/kilogram (J/kg) (radiation dose absorbed)	Gray (Gy)	1.000 000
kilotons	terajoules	4.183
kip (1000 lbf)	newton (N)	4.448 222 X E +3
kip/inch^2 (ksi)	kilo pascal (kPa)	6.894 757 X E +3
ktap	newton-second/m^2 (N-s/m^2)	1.000 000 X E +2
micron	meter (m)	1.000 000 X E -6
mil	meter (m)	2.540 000 X E -5
mile (international)	meter (m)	1.609 344 X E +3
ounce	kilogram (kg)	2.834 952 X E -2
pound-force (lbs avoirdupois)	newton (N)	4.448 222
pound-force inch	newton-meter (N·m)	1.129 848 X E -1
pound-force/inch	newton/meter (N/m)	1.751 268 X E +2
pound-force/foot^2	kilo pascal (kPa)	4.788 026 X E -2
pound-force/inch^2 (psi)	kilo pascal (kPa)	6.894 757
pound-mass (lbm avoirdupois)	kilogram (kg)	4.535 924 X E -1
pound-mass-foot^2 (moment of inertia)	kilogram-meter^2 (kg·m^2)	4.214 011 X E -2
pound-mass/foot^3	kilogram/meter^3 (kg/m^3)	1.601 846 X E +1
rad (radiation dose absorbed)	**Gray (Gy)	1.000 000 X E -2
roentgen	coulomb/kilogram (C/kg)	2.579 760 X E -4
shake	second (s)	1.000 000 X E -8
slug	kilogram (kg)	1.459 390 X E +1
torr (mm Hg, 0° C)	kilo pascal (kPa)	1.333 22 X E -1

*The becquerel (Bq) is the SI unit of radioactivity; 1 Bq = 1 event/s.
**The Gray (Gy) is the SI unit of absorbed radiation.

A more complete listing of conversions may be found in "Metric Practice Guide E 380-74," American Society for Testing and Materials.

1. INTRODUCTION

Engineering Decision Analysis Company, Inc. (EDAC) has provided engineering consulting services to Defense Nuclear Agency for the period from June 1978 to July 1979 under contract DNA001-78-C-0281. Services provided included the design and structural evaluation of containment structures and shock isolation systems: cost, feasibility and containment evaluations for future large cavity events and the data reduction and evaluation for experiment results. This work was sponsored under RDT&E RMSS Code K400078462J45HAXSX31102.

The contract work statement specified several tasks related to the DIABLO HAWK and MINERS IRON events. In addition, EDAC has provided additional support services on an as-needed basis as requested by the Contract Officers Representative. This work has been conducted over the past year with the results of each task being presented in a timely manner by reports or memos. This end-of-contract report is presented to document, in a single volume, the results of the various design and analysis tasks accomplished under this contract.

The engineering effort conducted during the contract period can be divided into eight major areas. These are: 1) Evaluation and Design of DIABLO HAWK Containment Structures and Shock Mounting including the U12n.11 drift overburden plug and Roses cubical and instrumentation rack shock mounting; 2) Analysis of the DIABLO HAWK Tunnel Environment Monitoring System (TEMS) Data; 3) Analysis of the DIABLO HAWK High Speed Camera Experiment; 4) Analysis of the HYBLA GOLD Tunnel Environment Monitoring System (TEMS) Data: 5) Investigations for Future Large Cavity Events including the evaluation of the load capacity of the RED HOT stemming plug and the cost and feasibility evaluation for excavation of large hemispherical cavities in Rainier Mesa; 6) Evaluation and Design of MINERS IRON Containment Structures including the TAPS, the U12n.03 over-

burden plug and the hardening of chiller line valves; 7) Evaluation and Design of the HURON KING LOS Pipe and Containment Structures including consulting on the fabrication of the LOS pipe, the design of the valve protection collar and the design of shock mounting for a large tank in an alternative horizontal LOS pipe configuration; and 8) Miscellaneous Items including the design of instrumentation rack shock mounting for future events, recommendations for friction tests of plywood on plexiglas slip planes and recommendations for the usage of expansive cement for containment structure designs.

In the sections which follow, a brief description of the various analyses or tasks is presented followed by all letters, memos and reports which were previously submitted individually and which document the effort. For some tasks, Project Officer's Reports have been published by DNA to document the work performed. In such cases, a reference to the subject report is provided and the report is not reproduced here.

2. EVALUATION OF DIABLO HAWK CONTAINMENT STRUCTURES AND SHOCK MOUNTING

The various containment structures for an underground nuclear event are intended to contain radioactive gases which might result from the detonation within a prescribed region. EDAC participated in the design and evaluation of most of the containment structures for the DIABLO HAWK event under previous contracts. However, before the DIABLO HAWK detonation, a drift being mined for the MINERS IRON event intersected the old U12n.03 drift. As a result, there was a potential leak path for radioactive gases around the main DIABLO HAWK overburden plug. Thus it was necessary to provide an additional overburden plug in the new MINERS IRON drift (U12n.11). This overburden plug is a concrete structure which blocks the U12n.11 drift and is held in place by a keyway around its circumference into the rock. The plug is designed to contain gases at pressure up to 69 bars (1000 psi) and to move integrally with the surrounding rock during ground shock.

Since the DIABLO HAWK event was the second event in the U12n.10 drift as part of the "two-in-one" concept with MIGHTY EPIC, the DIABLO HAWK working point was located 500 feet towards the portal from the MIGHTY EPIC working point. As a result, the common instrumentation rack and Roses cubical alcoves were 500 feet closer to the working point for DIABLO HAWK than for MIGHTY EPIC and would experience considerably larger ground shock. Consequently, EDAC provided design concepts for shock mounting of instrumentation racks and Roses cubicals which limited the accelerations transmitted to instrumentation to acceptable levels.

The following reports document the EDAC effort on the evaluation and design of DIABLO HAWK containment structures and shock mounting under contract DNA001-78-C-0281.

- U12n.11 Overburden Plug for the DIABLO HAWK Event, June 28, 1978, Page 2-3.

- Roses Cubical Shock Mounting System for DIABLO HAWK, July 14, 1978, Page 2-7.

- Shock Mounting of Racks for DIABLO HAWK, August 4, 1978, Page 2-11

- Rack Shock Mounting in Crosscut 3 for DIABLO HAWK, August 9, 1978, Page 2-15.

EDAC MEMO EDAC 177-042

TO: Joe LaComb

FROM: R. P. Kennedy DATE: June 28, 1978

SUBJECT: U12n.11 Overburden Plug for the DIABLO HAWK Event

Attached is a design sketch for an overburden plug to be located in the U12n.11 by-pass drift for the DIABLO HAWK event. This plug is to be situated between the U12n.10A and U12n.03 drifts at the transition of the 13 by 13 foot and 10 by 10 foot tunnel cross-sections. Design pressure and temperature are 1000 psi and 1000°F.

The attached design sketch represents minimum plug dimensions needed to resist the design temperature and pressure. The basic plug design is a 10 foot long keyway type plug with the keyway being 6 feet long and 3 feet deep. Note that the key should extend 2 feet back from the rockline at pressure loaded face of the plug and 3 feet back from the rockline at the opposite face as shown on the sketch.

This plug is to be made of concrete with a minimum unconfined compressive strength of 2500 psi. The concrete should be shrinkage compensating with positive expansion of 0.06 to 0.12 percent. If the concrete mix is not positive expanding, it is necessary to increase the keyway length from 6 to 7 feet such that the total plug length would become at least 11 feet.

We understand that it is planned to have 36 inch, 12 inch and 2 inch diameter pipes penetrating the plug. The 36 inch crawlway pipe will be sealed by Tube-Turn closures at each end and the other penetrations will be capped in the conventional manner. Minimum wall thickness for the 36 inch and 12 inch pipes are 0.75 and 0.25 inches, respectively. All penetrations will be located following conventional clearance guidelines and will have a minimum of 3 exterior gas block rings approximately equally

spaced through the length of the plug. The pressure loaded face of the plug will be covered by a steel bulkhead which is gas seal welded to be a leaktight barrier in the normal manner.

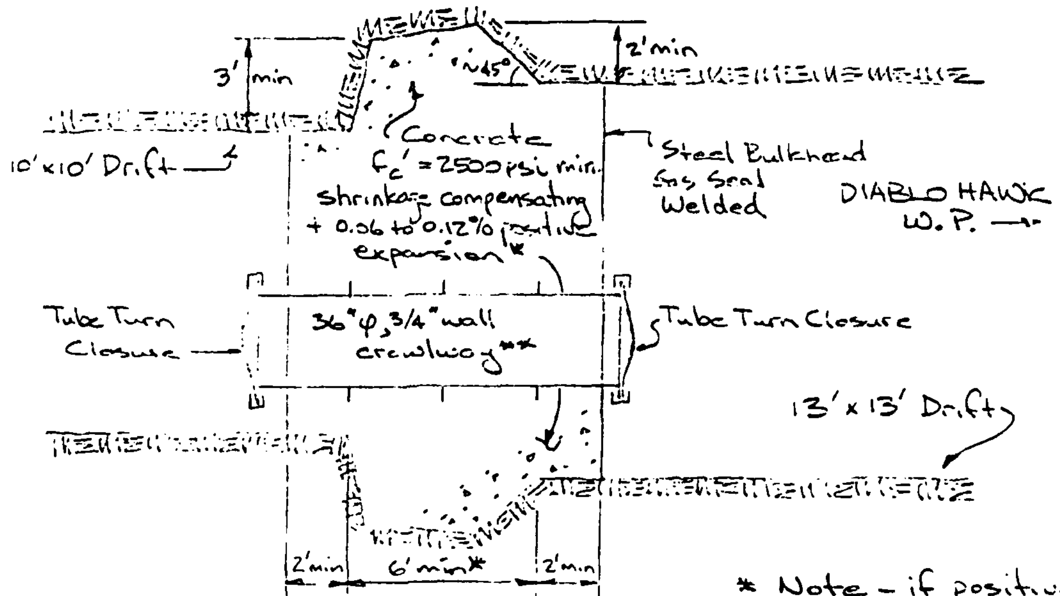
RPK:lca

cc: Bob Shirky, DNA
Frank Fuhriman, H&N

EDAC

BY SAS DATE 6/.. PROJECT [illegible] HAWK PAGE 1 OF 1
CHKD. BY ____ DATE ____ SUBJECT U12n.11 OBP JOB NO. 177-012

U12n.11 Overburden Plug



Elevation View

* Note - if positive expanding concrete mix is not used add one foot to the keyway length

** 12" φ penetration not shown should have 0.25" thick wal

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EDAC

MEMO

EDAC 177-042

TO: Joe LaComb

DATE: July 14, 1978

FROM: R. P. Kennedy R.P.K

SUBJECT: Roses Cubical Shock Mounting System for DIABLO HAWK

Sketches and design requirements for a shock mounting system which will isolate Roses cubicals from ground shock are presented in this memo. The cubicals considered are located in the U12n.10 by-pass drift between CS 5+90 and CS 6+60. A typical cubical has plan dimensions of 144 inches by 90 inches and a height of 98 inches. The cubical is assumed to weigh 6000 pounds including instruments, cribbing, and ballast. Should the cubicals vary from this weight by more than 1000 pounds, this design will have to be reconsidered.

A shock mounting system which is essentially the same as that used for MIGHTY EPIC has been found to be adequate for DIABLO HAWK . Sketches of this design are shown in Figure 1. The system consists of wood cribbing secured to the bottom of the cubical, styrofoam blocks secured to the wood cribbing and located as shown under the four bottom corners of the cubical, and a wood base plate connected to each styrofoam block which slides on a plexiglass sheet. The plexiglass provides a slip plane which limits the horizontal forces transmitted to the cubical. It also provides a non-conductive surface between the cubical and the ground. Each plexiglass sheet should be 1" thick and have minimum plan dimensions of 40" by 48". The styrofoam blocks limit the vertical forces transmitted to the cubical. These blocks should be Dow Styrofoam FR grade (or equivalent) with a density of approximately 2 lbs/ft^3 and a dynamic yield stress of 42 to 48 psi as determined at 20 percent strain. A block with a 10 inch square cross-section 12 inches high under each corner of the cubical will limit the peak vertical acceleration to less than 3.0 g's, providing the cubical weight lies between the limits stated above. Each block is expected to have a crush deformation of less than 3". This is less than the lockup deformation.

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Based on past results from dynamic analyses of Roses cubicals, the cubical could slide approximately 11" longitudinally and 6" transversely relative to the ground. To insure that the cubical will not ram an adjoining structure when sliding, a 16" horizontal longitudinal rattlespace and a 12" transverse rattlespace clearance is recommended about each cubical as shown in Figure 1. A vertical rattlespace of 6" is also recommended to allow for vertical movement.

RPK:RBN:lca

cc: Frank Fuhriman, H&N

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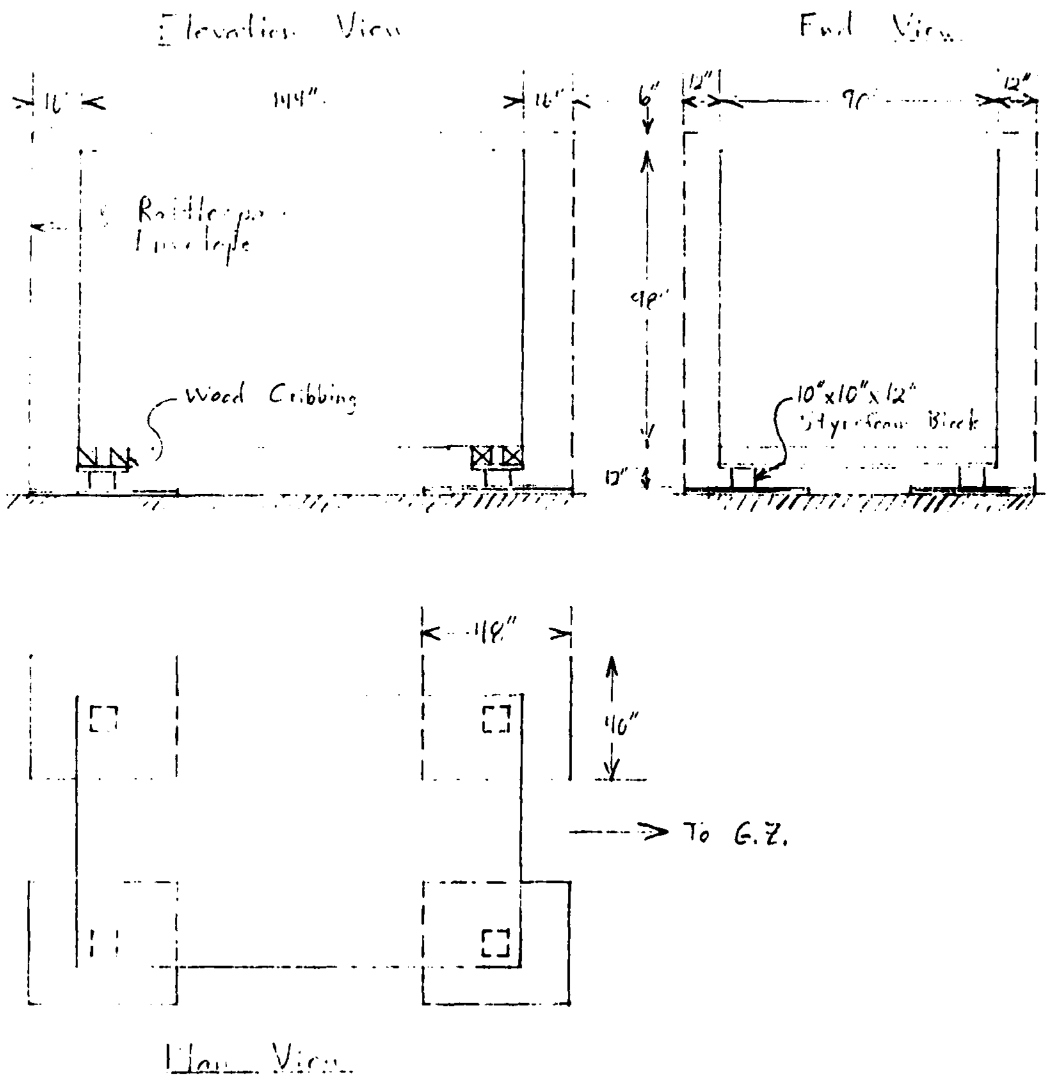
Figure [illegible]



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EDAC MEMO EDAC 177-042

TO: Joe LaComb

FROM: R. P. Kennedy RPK DATE: August 4, 1978

SUBJECT: Shock Mounting of Racks for DIABLO HAWK

This memo presents sketches and design requirements for a shock mounting system which will limit rack accelerations to 10g. The racks considered are located in TC-3 crosscut in alcoves 3-2, 3-4, 3-5, and 3-6. These racks are typically about 2 feet by 2 feet in plan with a height of about 6 feet and weigh between 580 and 1122 pounds. The one exception to these dimensions are the three Navy racks located in alcove 3-5. These racks are connected together such that they have overall plan dimensions of 28 inches by 72 inches and a height of 66 inches.

Sketches of the proposed design are shown in Figure 1. The system consists of suspending each rack from the back of the crosscut with nylon rope. The bottom of each rack is tied to the invert, also with nylon rope. The ropes are connected near each corner of the rack. The racks are to be suspended such that the distance between the top of each rack and the back is the same as the distance between the bottom of each rack and the invert. This distance is to be between 21 and 30 inches, depending on field conditions. A minimum clear distance of 12 inches should be maintained above and below the racks. The supports are located between adjacent racks such that one support can be used for two racks. The distance from the face of the rack to the support is to be a minimum of 11 inches and a maximum of 18 inches as shown in Figure 1. This will allow between 22 and 36 inches between racks. Supports should also be located no closer than 4 inches to any alcove partition. Back supports, such as rock bolts, and invert supports, such as redheads, should be designed to withstand 11 kips in tension and 3 kips in shear.

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The center of gravity of each rack should be near mid-height of the rack. If this is not the case, ballast should be added to empty shelves to move the c.g. to mid-height.

Racks weighing between 550 and 750 pounds should use 3/8 inch diameter nylon rope. Racks weighing between 750 and 1150 pounds should use 1/2 inch diameter nylon rope. This rope should be new and have the following average breaking strengths:

3/8 inch rope - 3350 pounds
1/2 inch rope - 5400 pounds

Both types of rope should have 19 percent elongation at 20 percent of their breaking strength. Berkley and Company's nylon twisted rope, Catalog Nos. NT608(1/2" rope) and NT606 (3/8" rope), is acceptable. Their address and phone number are:

Berkley and Company
Spirit Lake, Iowa 51360
(712) 336-1520

The nylon ropes used to support these racks should be tested to assure the above properties or the manufacturer should guarantee that these properties can be achieved. In addition, knots utilized to tie the ropes to the racks and supports should be adequate to provide near 100 percent of the rope breaking strength.

The connections between the racks in the triple Navy rack should be designed to withstand a total of 6 kips in both tension and shear. This rack should be suspended as the other racks (i.e., ropes at the 4 outer corners of the two outside rocks).

RPK:RBN:SAS:lca

cc: Frank Fuhriman

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BY ____ DATE ____ PROJECT ____ PAGE 1 OF 1

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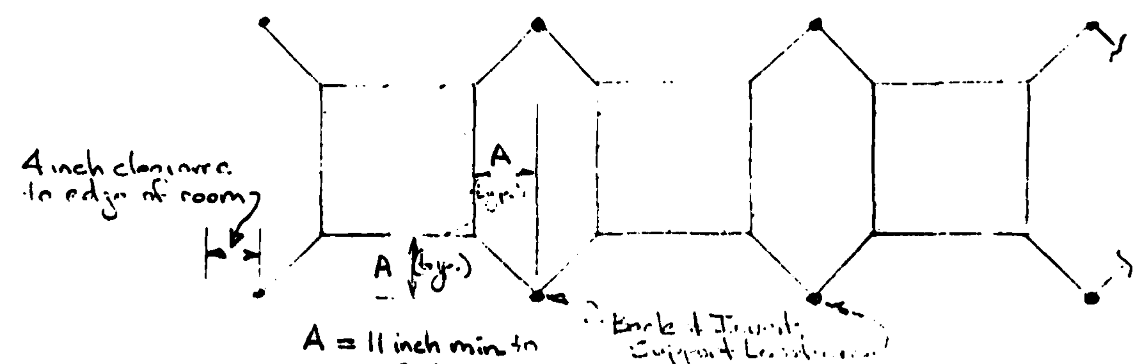
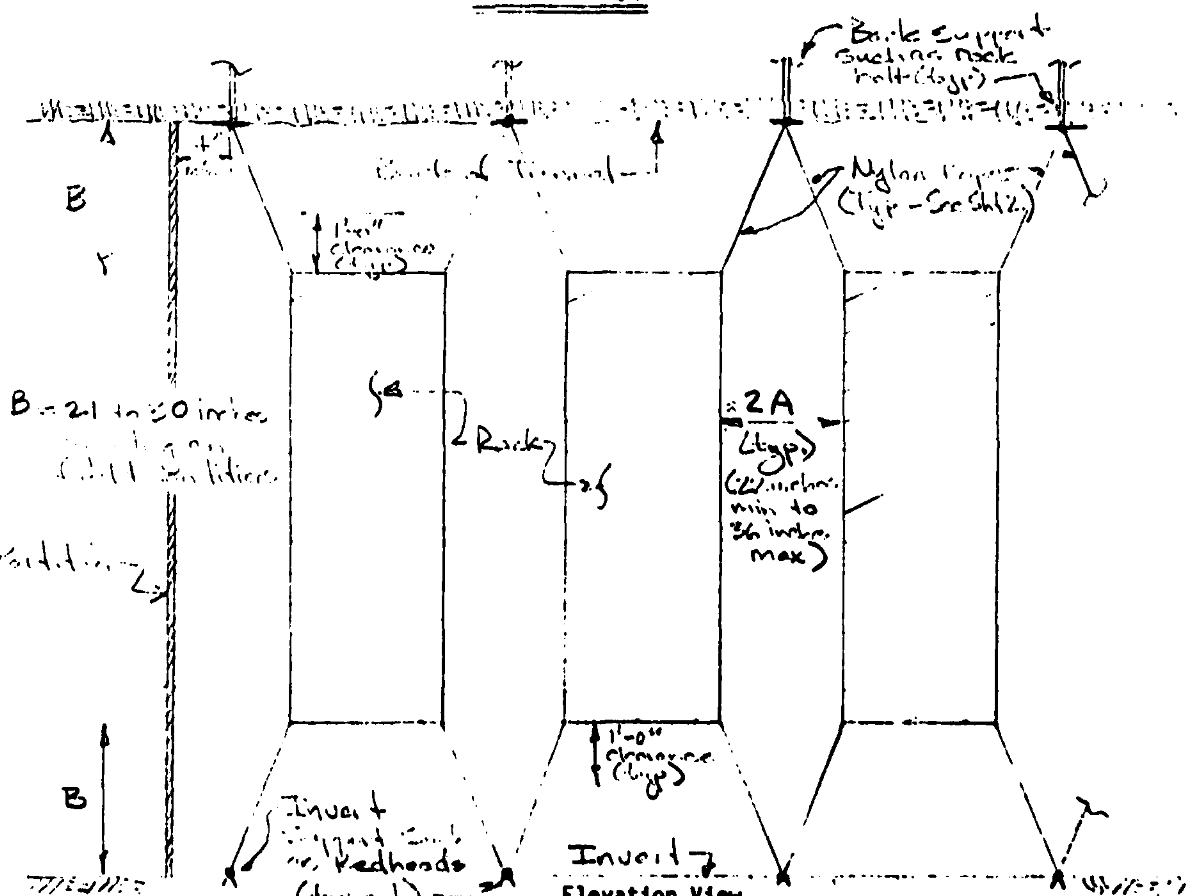


Plan View



Elevation View

EDAC MEMO EDAC 177-042

TO: J. LaComb

FROM: R. P. Kennedy *RPK* DATE: August 9, 1978

SUBJECT: Rack Shock Mounting in Crosscut 3 for DIABLO HAWK

Because the shock mounting system for the subject racks previously suggested (Memo from R. P. Kennedy to Joe LaComb dated August 4, 1978) was found to be impractical to install at this time, we have evaluated other systems and are submitting a revised recommended design. This revised design is expected to limit rack accelerations to 10g and although it may provide slightly greater risk than the suspended system previously suggested, we expect satisfactory performance during DIABLO HAWK. Note that the racks considered are in crosscut TC-3 in alcoves 3-2, 3-3, 3-5 and 3-6 and weigh between 580 and 1122 pounds.

Sketches of the revised design are shown on Figure 1. This design consists of styrofoam blocks (2 lbs/cu.ft density, 45 psi crushing strength) secured to the base of each rack with a wood base plate attached at the bottom of each sytrofoam block which slides on a plexiglass sheet. One sytrofoam block with dimensions of 6 inches by 6 inches by 6 inches high is required at the corner of each rack (four per rack). The Navy racks which are bolted together should have one block at each outside corner of the outermost racks. The connection between these racks should be capable of resisting 6 kips in both tension and shear.

The styrofoam block sizes described above are only applicable for racks which weigh at least 700 pounds. Therefore, racks which weigh less than 700 pounds should have ballast added to them. Ballast must be added in a symmetrical manner in plan view such that when weight is added near one face it is also added near the opposite face. It is advantageous for any additional weight to be placed towards the bottom of the rack such that the c.g. tends to be lowered.

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Racks may be either tied together (the preferred configuration) or separated. Racks which are tied together (See Figure 1) should still have 4 styrofoam blocks under each individual rack (with the exception of the Navy racks). These racks should be bound tightly with nylon rope. Adjacent racks should have cushioning material between them and secured to one of the racks (such as 2 inch thick sheets of Uniroyal "Esolite"). Racks which are not tied together should be separated by at least 12 inches.

The shock mounting design described above depends upon the racks being able to slide on the plexiglass sheet. Dynamic analyses of racks supported on foam blocks and subjected to the expected ground motion in Crosscut 3 indicate that they will not overturn provided that they can slide across the plexiglass sheet. Therefore, the wood base plates and plexiglass sheets should be clean and smooth at shot time. Plexiglass sheets should be arranged such that seams are at least 12 inches from working point sides of any styrofoam block as shown in Figure 2. On the portal side, it is acceptable for seams to be next to the face of the block. Also the edge of the plexiglass sheets should extend a minimum of 24 inches from the edge of the foam blocks on the working point sides and 16 inches on the portal sides. These clearances and an example layout of plexiglass sheets are illustrated in Figure 2.

An 18 inch clear space above the racks should be maintained in the event that the racks jump off the ground. Also, racks should be free to slide approximately 30 inches relative to the ground during ground shock. As a result, connecting cables should have enough slack to accommodate this movement. Otherwise, these cables may be severed or tend to overturn the rack. Note that the rack movements described above are conservative upper limit estimates and if these values cause great difficulties, it may be possible to reduce the requirements for cable slackness. We would not recommend that the top of these racks be tied to the back of the tunnel or to the unistrut overhead. This additional restraint is not necessary and if not properly designed may be detrimental as it may increase the transmitted accelerations to the rack and tend to cause overturning.

RPK:SAS:cs

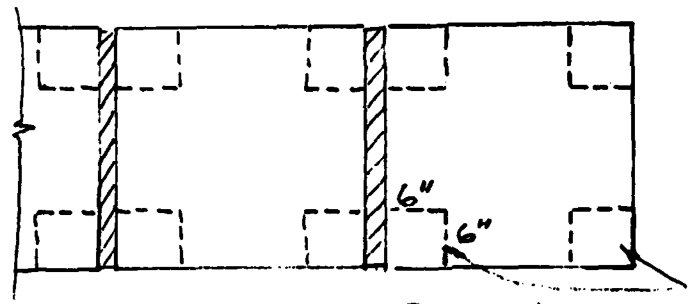
cc: Frank Fuhriman

EDAC

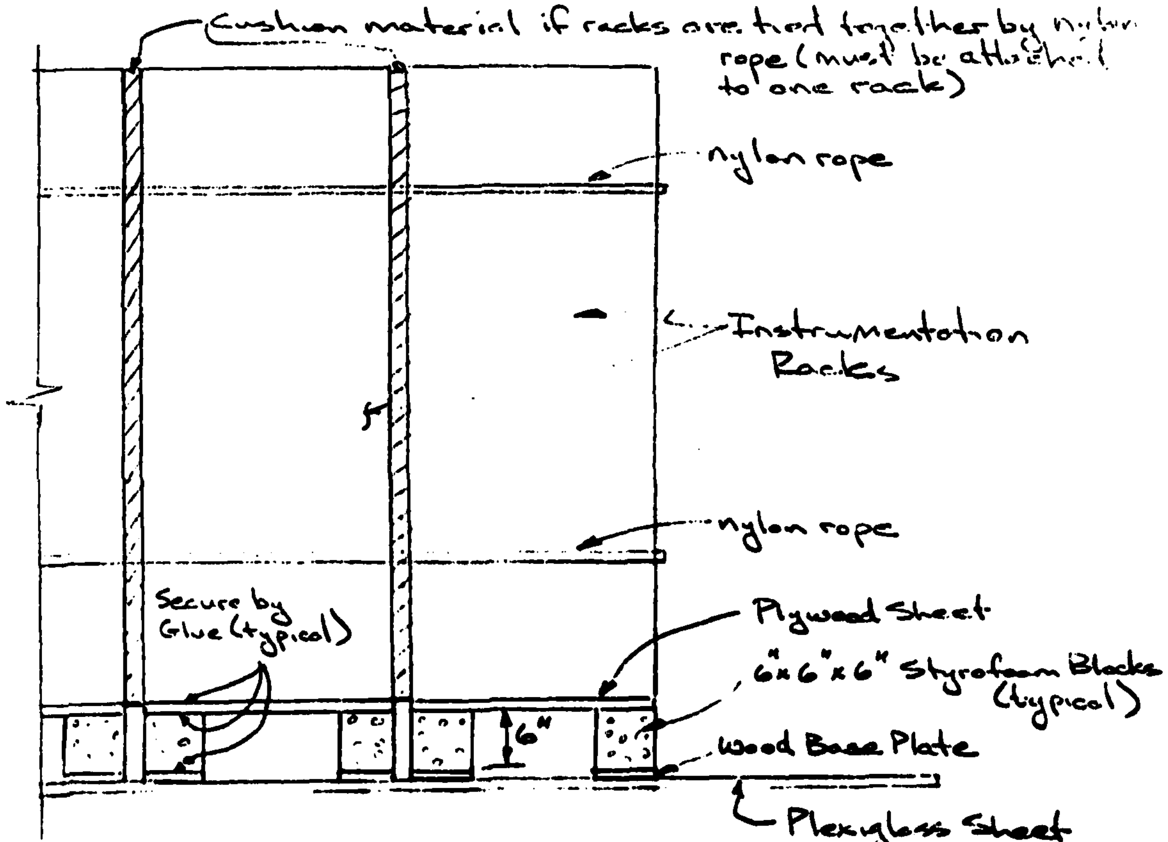
EDAC

BY [illegible] DATE 8/8/73 PROJECT [illegible] PAGE 1 OF 2
CHKD. BY ____ DATE ____ SUBJECT Rack Shock Mounting JOB NO. [illegible]

Notes
1. 12" clearance between racks if not tied together
2. 18" clear space above racks
3. Connecting cables should have slack enough for 30 inch movement of rack relative to the ground



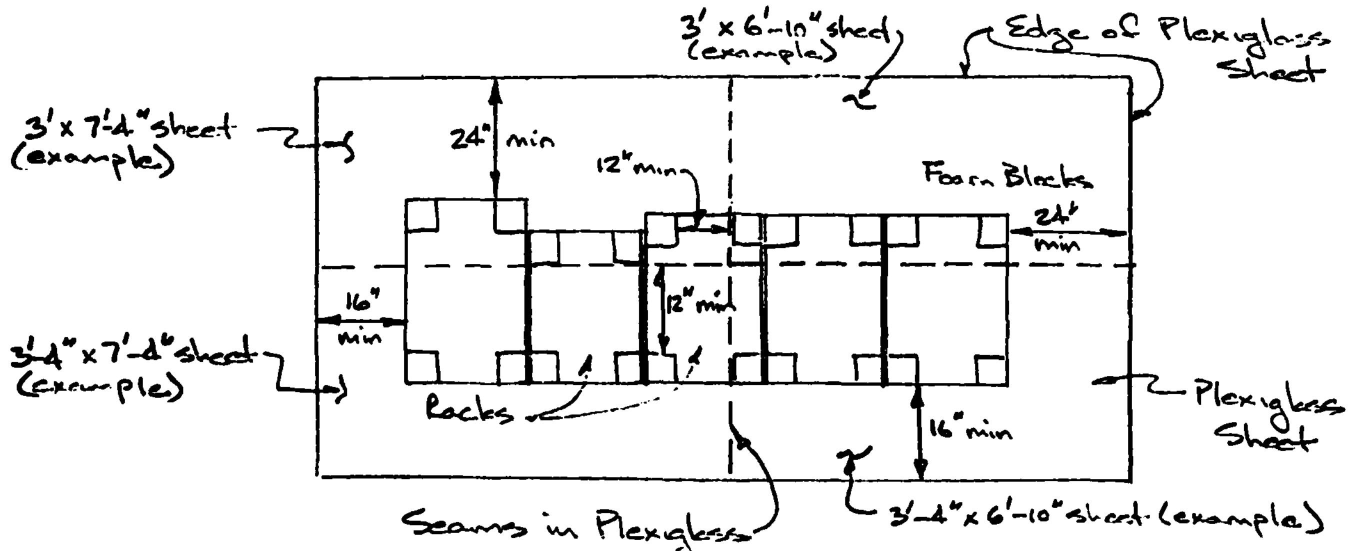
Plan View



Elevation View

Plan View of Racks tied together with example layout of plexiglass sheets

W.P.



Clearance Summary	
Location	Minimum Clearance
1. Edge of Foam Block to Edge of Plexiglass—Working Point Direction	24"
2. Edge of Foam Block to Edge of Plexiglass—Portal direction	16"
3. Edge of Foam Block to Seam—W.P. Direction	12"
4. Edge of Foam Block to Seam—Portal Direction	0

3. DIABLO HAWK TEMS DATA REDUCTION

The Tunnel Environment Monitoring System (TEMS) experiment was designed to measure variations in pressure and temperature resulting from the DIABLO HAWK event. The data was gathered over time periods ranging from minutes to days following the event. Twenty-nine environment data points were monitored during and subsequent to the DIABLO HAWK event by means of the TEMS.

The primary purpose of the TEMS is to evaluate the effectiveness of the gas containment system consisting of drift stemming and containment structures. Also, the TEMS provides a real time display of tunnel environment measurements at the DNA monitor room and provides for the automatic pressurization of the air chamber between the Gas Seal Plug and Gas Seal Door and the maintenance of this differential pressure across the Gas Seal Plug. The DIABLO HAWK TEMS also monitored a number of ground zero extreme environment pressures and temperatures.

The following report documents the results of the DIABLO HAWK TEMS experiment.

- HUSSAR SWORD SERIES, DIABLO HAWK Tunnel Environment Monitor System (TEMS), Description, Performance and Measured Data, POR 6996, June 1979. (This report may be obtained through Director, Defense Nuclear Agency, Washington, D. C. 20305).

4. DIABLO HAWK HIGH SPEED CAMERA EXPERIMENT

Two experiments associated with the DIABLO HAWK event were the MIGHTY EPIC/DIABLO HAWK Block Motion experiment and the Cavity Size Effects experiment both of which employed high speed photography as an instrumentation technique. In support of these experiments, Defense Nuclear Agency installed eight (8) high speed camera systems, including power, lighting, targets, and time reference in the CB, F, and G structures drifts of the U12n.10A tunnel complex. These cameras took high speed photographs of the tunnel response to the ground motion generated by the nuclear device. Visual targets were attached to rockbolts embedded at various drifts in the back, sides, and invert of the drifts. Other visual targets such as free impulse masses, scratch gages and flying particles were also monitored. Two (2) additional cameras were installed on the surface of Rainier Mesa in order to monitor the behavior of the shock isolation system employed for the data acquisition trailers. The ten high speed camera systems described above comprise the DIABLO HAWK High Speed Camera experiment.

Response data have been digitized from the film records for all targets from which reliable data could be obtained and a report presenting the quantitative results of the data reduction effort is being prepared. Specifically, displacement time-histories will be presented for targets attached to embedded rockbolts, for gravity reference targets, impulse targets, scratch gages and for flying rock particles. Also, time of initiation of significant tunnel responses are recorded. Based upon these data, target velocities, spall velocities, maximum displacements, and peak rock strains at various depths will be estimated.

preceding page blank

The following report documents the results of the DIABLO HAWK High Speed Camera Experiment.

- HUSSAR SWORD SERIES, DIABLO HAWK EVENT, Ground Motion Studies by High Speed Photography (U), POR 7024, August, 1979, (This report may be obtained through Director, Defense Nuclear Agency, Washington, D. C. 20305).

5. HYBLA GOLD TEMS DATA REDUCTION

In the latter part of November 1977, EDAC was commissioned to prepare the Final Project Officers Report for the HYBLA GOLD Tunnel Environment Monitoring System (TEMS) Experiment. TEMS provides long-term recording of tunnel pressures and temperatures. The preparation of the Final Project Officers Report entailed the gathering of system design information and the obtaining of pressure and temperature data records from 28 instruments located between ground zero and the Gas Seel Door. Magnetic tape data, strip chart recorder data, and hand gathered digital meter data were all used to determine parameter values preshot, during the event, and postshot to as much as 28 days after the HYBLA GOLD event.

The primary purpose of the Tunnel Environment Monitoring System (TEMS) is to provide long-term post event recording of tunnel pressures and temperatures in order to evaluate the effectiveness of the gas containment system consisting of the drift stemming and the various drift plugs. In addition, the TEMS is designed to provide a real-time display of the tunnel environment measurements at the Defense Nuclear Agency (DNA) monitor room at Control Point 1. A secondary objective includes the automatic pressurization of the air chamber between the Gas Seal Plug and the Gas Seal Door and the maintenance of this differential pressure across the Gas Seal Plug.

The TEMS for the HYBLA GOLD event was also called upon to monitor a significant number of ground zero and main drift pipe extreme environment pressures and temperatures in addition to the normal containment instrumentation. This marked the first time that an attempt was made to monitor the extreme environment by means of the TEMS.

The following report documents the results of HYBLA GOLD TEMS data reduction.

- HUSSAR SWORD SERIES, HYBLA GOLD EVENT, Tunnel Environment Monitor System (TEMS), Description, Performance and Measured Data, POR 6978, January 1979. (This report may be obtained through Director, Defense Nuclear Agency, Washington, D. C. 20305).

6. INVESTIGATIONS FOR FUTURE LARGE CAVITY EVENTS

In order to provide large space for the fielding of experiments for underground nuclear tests, large cavity events are being considered. EDAC has conducted investigations for DNA in support of planning for possible, future large cavity events. These investigations include a cost and feasibility study for the construction of hemispherical cavities and the evaluation of containment structure load capacities from RED HOT, a past large cavity event.

A cost and feasibility program was performed considering hemispherical cavities between 24.4 and 91.4 meters (80 and 300 ft) in diameter. The rock support designs for the cavities are based upon the use of internally installed rockbolts for the smaller cavities and tendons installed from annular galleries for the larger chamber. The evaluation program included research into past experience pertaining to the excavation and support of large underground caverns, assessment of the geological conditions which exist in Rainier Mesa, preliminary design of the cavities and their rock support system based upon the geological setting, development of mining plans for the excavation of the caverns, and estimation of the cost and manpower schedule to complete the construction of each size chamber based upon the preliminary design and mining approach. The final report presents the finding of the cost and feasibility evaluation program and includes recommendations concerning the maximum practical chamber size considering schedule, dollar, and state-of-the-art constraints.

The pressure capacities of the stemming plugs and the behavior of the debris plug from the RED HOT event were evaluated. The purpose of this effort is to understand the pressures resulting in the tunnel during this event such that containment along the tunnel for large cavity events similar to RED HOT in the future may be reliably designed.

The following reports document the EDAC investigations for future large cavity events under contract DNA001-78-C-0281.

- Cost and Feasibility Evaluation for the Excavation of Large Hemispherical Cavities in Rainier Mesa, October 1978. (This report may be obtained through Director, Defense Nuclear Agency, Washington, D. C. 20305).
- RED HOT Stemming Plug Evaluation, October 16, 1978, Page 6-3.

EDAC MEMO EDAC 177-044

TO: Joe LaComb

FROM: R. P. Kennedy DATE: October 16, 1978

SUBJECT: RED HOT Stemming Plug Evaluation

The pressure capacities of the stemming plugs and the behavior of the debris plug from the RED HOT event have been evaluated and are reported herein. The purpose of this effort is to understand the pressures resulting in the tunnel during this event such that containment along the tunnel for large cavity events similar to RED HOT in the future may be reliably designed.

Tunnel stemming for the RED HOT event consisted of a series of plugs as follows:

Plug #1	-	25 foot long sand plug.
Plug #2	-	12 foot long keyed concrete seat with a 6 foot diameter, 1-1/2 inch thick conical steel door.
Plug #3	-	10 foot long keyed concrete collar with a 5 foot by 6 foot by 4 foot long poured-in-place concrete cork.
Plug #4	-	8 foot long keyed concrete collar with a 7 foot by 8 foot by 8 foot long movable concrete cork.

Plug #1 is nearest to the working point with plugs #2, 3 and 4 progressively further out from the working point. Plug #4 is located approximately 700 feet from the working point.

Upon reentry it was noted that Plugs 3 and 4 were no longer in place with only the keyways remaining. Reentry did not extend to the locations of Plugs 1 and 2 and thus no observations of these plugs were made. At approximately 1900 feet from the working point, a debris plug had formed where no plug has existed before the shot. Characteristics of this debris plug such as length, weight or density are not known. It was noted that this debris plug allowed only minor leakage and there had been no obvious leak paths eroded through it.

The ultimate static pressure capacity of the three concrete plugs (#2, 3 and 4) have been estimated. The capacity of the sand plug has not been considered as this plug could not be relied upon to resist pressure loading. For the sand plug, it is possible that during ground shock, the sand would compact, leaving an open leak path along the back of the tunnel. With this occurrence, the sand plug could easily be eroded away. For the concrete plugs, the ultimate pressure capacity has been estimated from empirical data for concrete structures with a low span to depth ratio. Static capacities for these plugs are summarized below:

Ultimate Static Pressure Capacity (bars)

Plug	Lower Estimate	Upper Estimate
2	190	280
3	380	600
4	230	360

Note that it is estimated that the actual static pressure capacity has about a 70 percent probability of being within the upper and lower estimates given above. Also, it is believed that the static pressure capacities given above are reasonable estimates of the ultimate dynamic pressure load capacity. The expected mode of failure for these plugs is punching shear and for such non-ductile behavior the dynamic capacity is not expected to differ significantly from the static capacity.

The behavior of the debris plug during the RED HOT event has been investigated on the basis of a rigid body dynamic analysis. From this analysis, the pressure load which would move the debris plug down the tunnel and stop at the observed location has been evaluated. The rigid body dynamic analysis procedure is illustrated schematically on Figure 1. A triangular pressure pulse acting on the working point face of the debris plug beginning immediately after the failure of plug #4 is considered. The pressure pulse for which the debris plug moves 1200 feet to the final location is determined. Note that it is necessary to estimate the weight of the debris plug and its resistance to movement down the tunnel.

The weight of the debris plug has been calculated from the weight of the four stemming plugs plus the weight of tunnel sets, lagging, rails and vent pipes from the working point to the debris plug location. Because the weight of the debris plug is increasing as it collects sets, lagging, rails and vents travelling down the tunnel, an average weight has been used for the analysis considering added weight over half the distance from Plug #4 to the final debris plug location. The resistance to movement along the tunnel has been computed as the summation of the compressive strength of the wood lagging around the perimeter of the tunnel and friction. Lagging consists of 3 inch by 12 inch by 6 foot long boards framed between tunnel sets. Strength properties of standard Douglas Fir have been assumed in the resistance calculation. Friction resistance has been taken as the debris plug weight multiplied by a friction coefficient. Considering the irregular surfaces of the plug and tunnel, a median friction coefficient of 1.2 has been considered appropriate and utilized in the resistance calculation.

The debris plug weight, an estimate of the plug length and the resistance to movement along the tunnel are summarized below:

Debris Plug Property	Lower Estimate	Upper Estimate
Weight	2300 kips	3500 kips
Length	70 feet	115 feet
Pressure Resistance	16 bars	27 bars

The actual properties are expected to have a 70 percent probability of being within the upper and lower estimates. Note that the lengths are computed based on a median density of 140 pcf. A density in this range is considered reasonable because there was not major leakage of the debris plug. The resistance value given is the pressure acting on the working point face of the debris plug which could be resisted statically by the compressive strength of the wood lagging and by friction between the plug and tunnel.

The behavior of the debris plug has been analyzed (see Figure 1) by considering triangular pressure pulses with durations of 5, 10, 20 and 40 seconds and determining the peak pressure for which the debris plug would travel 1200 feet from the location of Plug #4 and stop. The results of these analyses are illustrated on Figure 2. This figure shows that greater peak pressures are possible at shorter durations and lesser pressures are possible at longer durations. Analyses of the debris plug indicate that the plug stops in approximately 10 seconds after the failure of Plug #4 and that the average pressure over this 10 second period must be less than 30 bars for the analytical results to agree with the reentry observations. The calculated time at which the debris plug stops does agree with field evidence. Geophone data indicates that the debris plug stopped at about 12 or 13 seconds after the detonation or about 10 seconds after the estimated time of failure for Plug #4. It should be noted that the analyses performed assume that the debris plug has zero acceleration and velocity immediately after the failure of Plug #4. However, these initial conditions are not a significant factor compared to the pressure loadings considered.

In conclusion, reentry to the RED HOT test area revealed the failure of at least two of the tunnel stemming plugs (#3 and 4) and the formation of a debris plug at a location where there had not been a plug or constriction prior to the detonation. Analyses of the stemming plugs and debris plug have been conducted in order to determine the forces acting within the tunnel following RED HOT. In order for the analyses to agree with the observations made during reentry, the following conclusions may be reached.

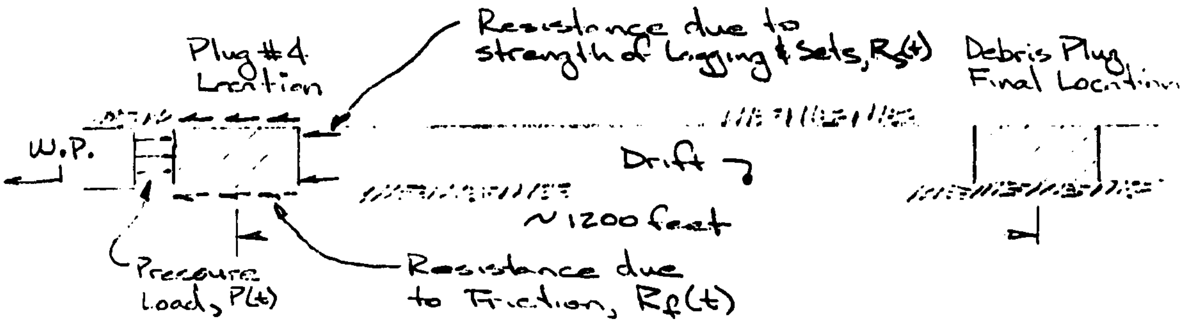
a. Peak pressures of at least 400 bars must have been reached in order to fail the tunnel stemming plugs.

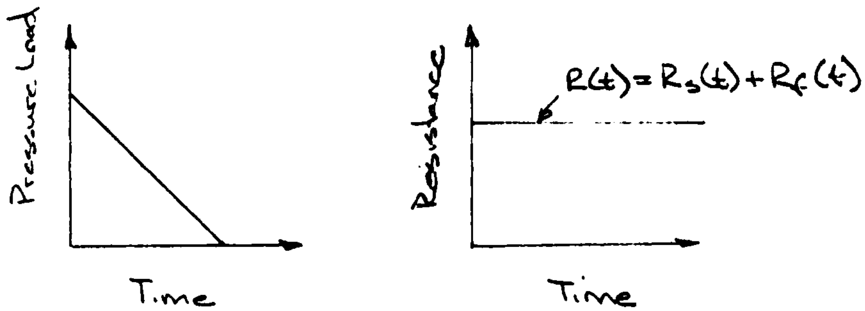
b. The debris plug stopped in approximately 10 seconds (plus or minus 5 seconds) after the failure of Plug #4.

c. Over the 10 second period following the failure of Plug #4, the average pressure must have been less than 30 bars in order for the debris plug to have stopped at the observed location.

RPK:SAS:lca

cc: C. Keller, FCTMC





Plug Acceleration, $a(t) = \left[\frac{P(t) - R(t)}{W}\right] A_L$

$P(t)$ = Pressure Load

$R(t)$ = Pressure Resistance

W = Plug Weight

A_L = Loaded Area

Figure 1

Debris Plug Rigid Body Dynamic Analysis

EDAC

BY: EAC DATE: 9/27/78 PROJECT: DNA RED HOT PAGE: 2 OF 2

CHKD. BY: ______ DATE: ______ SUBJECT: Pressure Pulse on Debris Plug JOB NO. 177-011

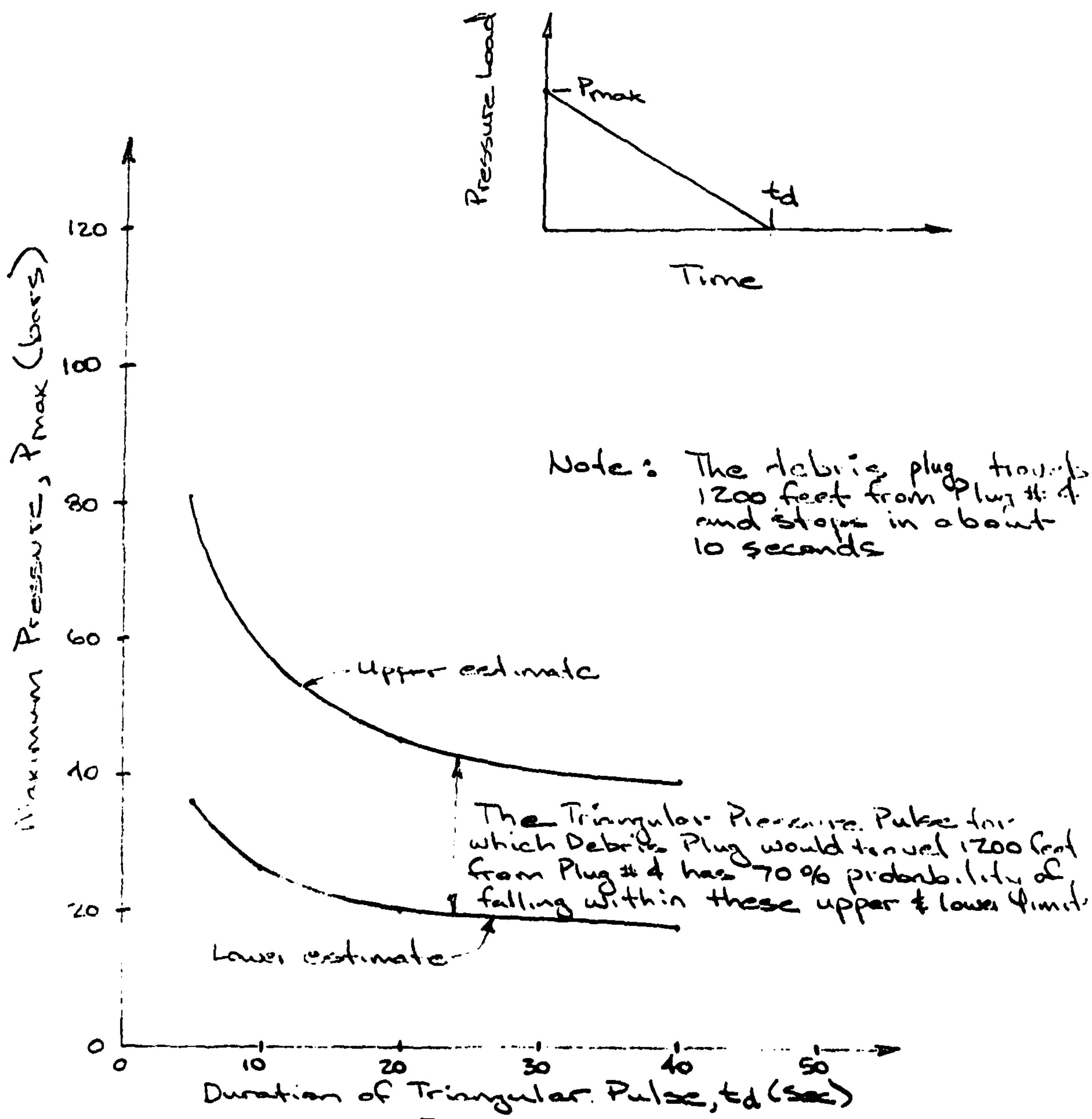


Figure 2

Pressure Pulse at which Debris Plug Would stop at the Observed Location

7. MINERS IRON CONTAINMENT STRUCTURES

The MINERS IRON event will be conducted in the U12n tunnel complex. This tunnel complex was also used for the MIGHTY EPIC and DIABLO HAWK events recently. As a result, it is possible for MINERS IRON to utilize the same location and design of some containment structures as were used for DIABLO HAWK. This was done for the main overburden plug and the gas seal plug. In addition, the DIABLO HAWK TAPS housing and the identical TAPS plug design were employed at the MINERS IRON location. Also, the hardening of chiller lines at the vent downhole is identical to that used on previous events. Consequently, considerable cost savings was achieved by using past designs and the EDAC design and evaluation effort was minimized for MINERS IRON containment structures.

However, EDAC did conduct a significant design and evaluation effort for the overburden plug which blocks the potential leakpath around the main overburden plug along the U12n.03 drift. This plug was originally designed in the U12n.03 drift but had to be redesigned after it was discovered that the drift was overbroken more than originally expected. Then, the location of the MINERS IRON working point was changed such that it was much closer to the U12n.03 overburden plug location and design considerations for ground shock became very serious. As a result, plug designs were evaluated at three candidate locations with design concepts which move integrally with the surrounding rock and resist the design pressure and temperature loading being recommended at each location.

The following reports document the EDAC effort on MINERS IRON containment structures conducted under contract DNA001-78-C-0281.

- MINERS IRON TAPS Plug and Housing, February 16, 1979, Page 7-3.

- MINERS IRON Overburden Plug and Gas Seal Plug, March 14, 1979, Page 7-5.

- Hardening of Chiller Line Valves at the Vent Downhole for MINERS IRON, March 14, 1979, Page 7-7.

- MINERS IRON U12n.03 Drift Overburden Plug, March 12, 1979, Page 7-9.

- MINERS IRON U12n.03 Drift Overburden Plug, May 4, 1979, Page 7-13.

- MINERS IRON U12n.12 and U12n.03 Drift Overburden Plug, June 4, 1979, Page 7-15.

EDAC

177-040

MEMO

TO: Joe LaComb DATE: February 16, 1979

FROM: R. P. Kennedy RPK

SUBJECT: MINERS IRON TAPS Plug and Housing

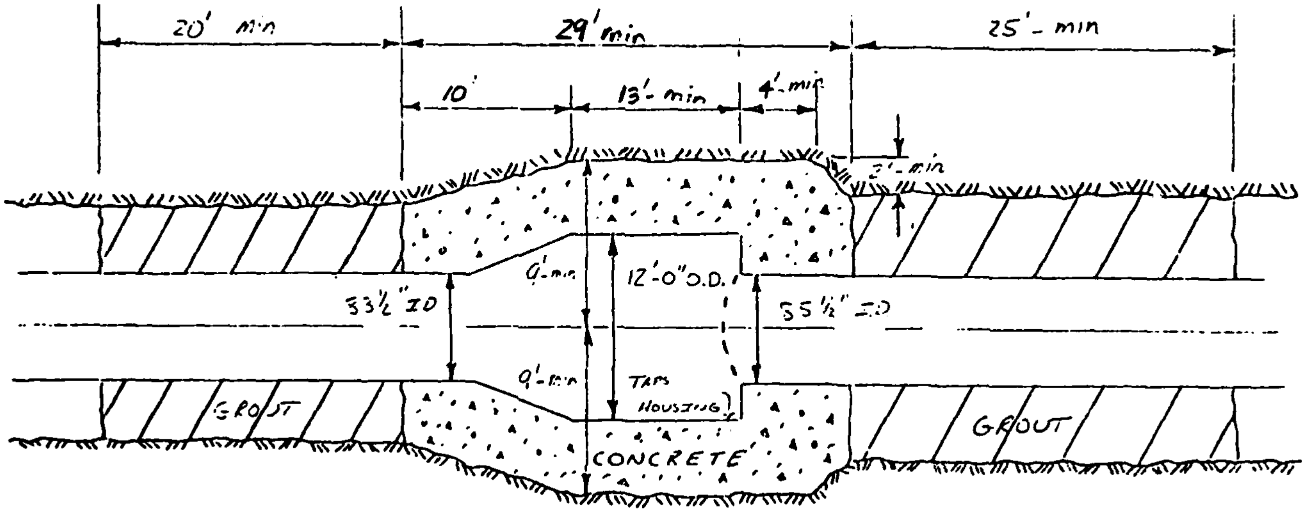
Based on a review of the design basis for the DIABLO HAWK TAPS and of the proposed configuration for the MINERS IRON TAPS, we can conclude that the reuse of the DIABLO HAWK TAPS housing along with a concrete and grout plug similar to that used for DIABLO HAWK will provide an adequate design for the MINERS IRON event. The MINERS IRON TAPS plug should conform to the minimum dimensions specified for the DIABLO HAWK TAPS plug (EDAC memo dated September 2, 1976). A sketch of the plug dimensions taken from the DIABLO HAWK memo is attached.

cc: A. C. Hollins, H&N, Area 12

EDAC

BY ________ DATE ________ PROJECT ________ PAGE ____ OF ____

CHKD. BY ________ DATE ________ SUBJECT ________ JOB NO. ________



Notes: Design based on drift being approximately 14' by 14'
Concrete — $f_c' = 5000$ psi
Grout — $f_c' = 4000$ psi

PLAN VIEW OF [illegible]

TAPS HOUSING AND PLUG

EDAC MEMO EDAC 177-040

TO: Joe LaComb

FROM: R. P. Kennedy RPK

SUBJECT: MINERS IRON Overburden Plug and Gas Seal Plug

The plan for the MINERS IRON overburden and gas seal plug is to utilize an identical design to those used for DIABLO HAWK and to locate these plugs at the DIABLO HAWK locations. All concrete from the DIABLO HAWK plugs will be mined out to the rock line. This approach is expected to provide as reliable containment for MINERS IRON as the original DIABLO HAWK structures.

RPK:SAS:lca

cc: A. C. Hollins - H&N, Area 12

EDAC 177-040

MEMO

TO: Joe LaComb March 14, 1979

FROM: R. P. Kennedy RPK

SUBJECT: Hardening of Chiller Line Valves
at the Vent Downhole for MINERS IRON

Prior to the DIABLO HAWK event, supporting members for the chiller line valves at the U12n common vent downhole on the mesa surface were designed for the maximum expected ground shock conditions from future planned events in the vicinity of the downhole. The MINERS IRON working point is 1200 feet from the U12n common vent downhole and the expected ground shock conditions are equal to those used to design the chiller line supporting members. As a result, the supporting members for chiller line valves on the mesa surface as described in the EDAC memo dated September 29, 1977 is an adequate design for the MINERS IRON event. In addition, the supporting structure for the chiller line valves at the vent downhole alcove plug at the tunnel level as described in the EDAC memo dated September 23, 1977 is also an adequate design for the MINERS IRON event.

cc: A. C. Hollins - H & N, Area 12

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EDAC MEMO EDAC 177-040

TO: Joe LaComb

FROM: R. P. Kennedy RPK DATE: March 12, 1979

SUBJECT: MINERS IRON U12n.03 Drift Overburden Plug

Attached is a design sketch for an overburden plug to be located in the U12n.03 drift adjacent to the U12n.11 main drift for the MINERS IRON event. The drift at the plug location is a 10 foot by 10 foot horseshoe cross-section with possible overbreakage to a 12 foot wide by 13 foot high section. Design pressure and temperature are 1000 psi and 1000°F. We understand that there will be a grout plut at the working point side of the overburden plug. However, the overburden plug design presented here stands by itself and does not take advantage of the grout plug.

The attached design sketch represents minimum plug dimensions needed to resist the design pressure and temperature. The basic plug design is a 13 foot long keyway type plug with the keyway being 9 feet long and 3 feet deep. The plug is to be made of concrete with a minimum unconfined compressive strength of 2500 psi. The concrete should be shrinkage compensating.

It is planned to have a 36 inch diameter crawlway pipe penetrating this plug. This crawlway will be sealed at the working face by a blind flange gas seal welded to it. In addition, this crawlway will have redundant gas blockage by either placing a Tube-Turn closure at the portal end or by filling the crawlway with grout and providing three 3-inch deep gas block rings inside the crawlway as well as a portal face blind flange. Minimum wall thickness for the 36 inch diameter crawlway pipe is 0.75 inches.

(continued)

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The crawlway and any other penetrations will be located following conventional clearance guidelines and will have a minimum of 3 exterior gas block rings approximately equally spaced through the length of the plug. The working point face of the plug will be covered by a steel bulkhead which is gas seal welded to be a leaktight barrier in the normal manner.

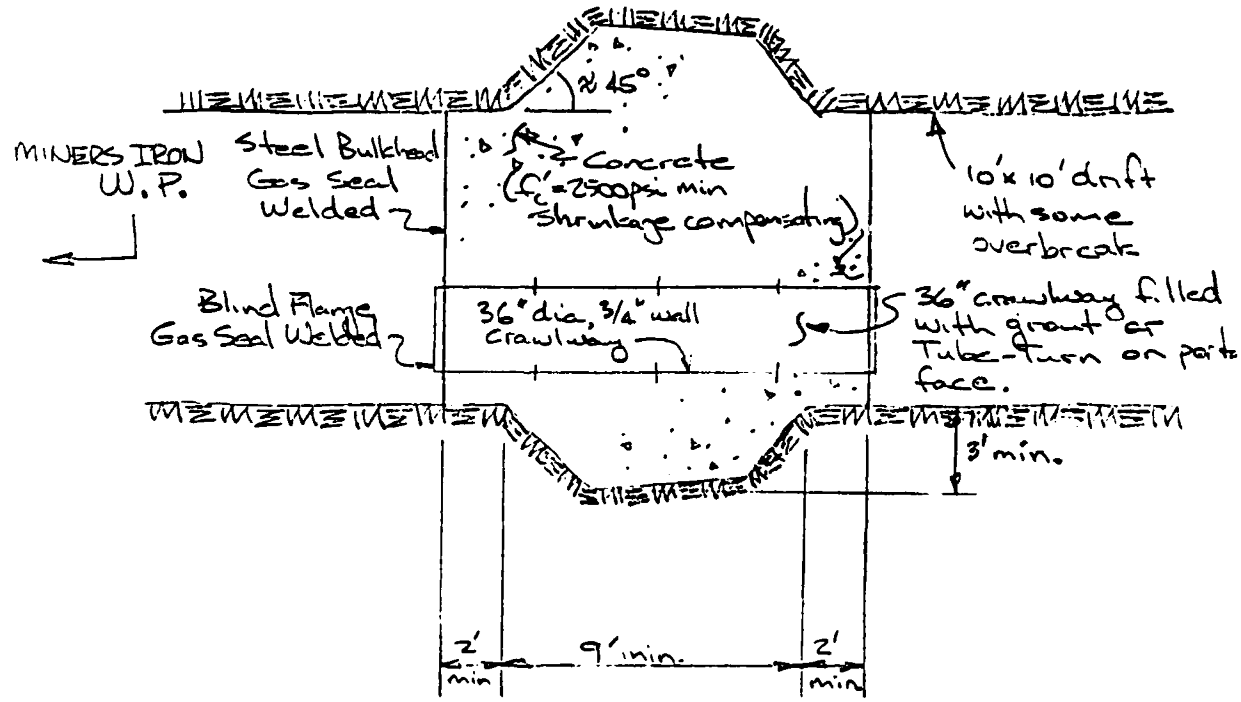
RPK:SAS:lca

Attachment

cc: A. C. Hollins - H&N Area 12

BY SAS DATE 3/12/79 PROJECT DNA (MINERS IRON) PAGE 1 OF 1
CHKD. BY ____ DATE ____ SUBJECT U12n.03 OBP JOB NO. 177-040

MINERS IRON U12n.03 Overburden Plug



Elevation View

Notes.

1. All penetrations should have a minimum of 3 exterior gas block rings approximately equally spaced thru the plug length.
2. The 36" crawlway should have a minimum of 3 - 3 inch deep interior gas block rings approximately equally spaced thru the plug length.

EDAC

To : Joe LaComb

From : R. P. Kennedy RPK **Date :** May 4. 1979

Subject : MINERS IRON U12n.03 Drift Overburden Plug

Reference :

Attached is a design sketch for an overburden plug to be located in the U12n.03 drift adjacent to the U12n.11 main drift for the MINERS IRON event. This overburden plug design supersedes the design previously submitted on March 12, 1979 because we have been informed that the drift size at the plug location is actually 18 feet high by 15 feet wide. The previously submitted design was based on a 10 foot by 10 foot horseshoe drift with possible over-breakage to a 12 foot wide by 13 feet high cross section. Design pressure and temperature are 1000 psi and 1000°F. We understand that there will be a grout plug at the working point side of the overburden plug. However, the overburden plug design presented here stands by itself and does not take advantage of the grout plug.

The attached design sketch represents minimum plug dimensions needed to resist the design pressure and temperature. The basic plug design is a 16 foot long keyway type plug with the keyway being 12 feet long and 3.5 feet deep. The plug is to be made of concrete with a minimum unconfined compressive strength of 2500 psi. The concrete should be shrinkage compensating.

It is planned to have a 36 inch diameter crawlway pipe penetrating this plug. This crawlway will be sealed at the working face by a blind flange gas seal welded to it. In addition, this crawlway will have redundant gas blockage by either placing a Tube-Turn closure at the portal end or by filling the crawlway with grout and providing three 3-inch deep gas block rings inside the crawlway as well as a portal face blind flange. Minimum wall thickness for the 36 inch diameter crawlway pipe is 0.75 inches.

The crawlway and any other penetrations will be located following conventional clearance guidelines and will have a minimum of 3 exterior gas block rings approximately equally spaced through the length of the plug. The working point face of the plug will be covered by a steel bulkhead which is gas seal welded to be a leaktight barrier in the normal manner.

Attachment
cc: A. C. Hollins - H&N Area 12

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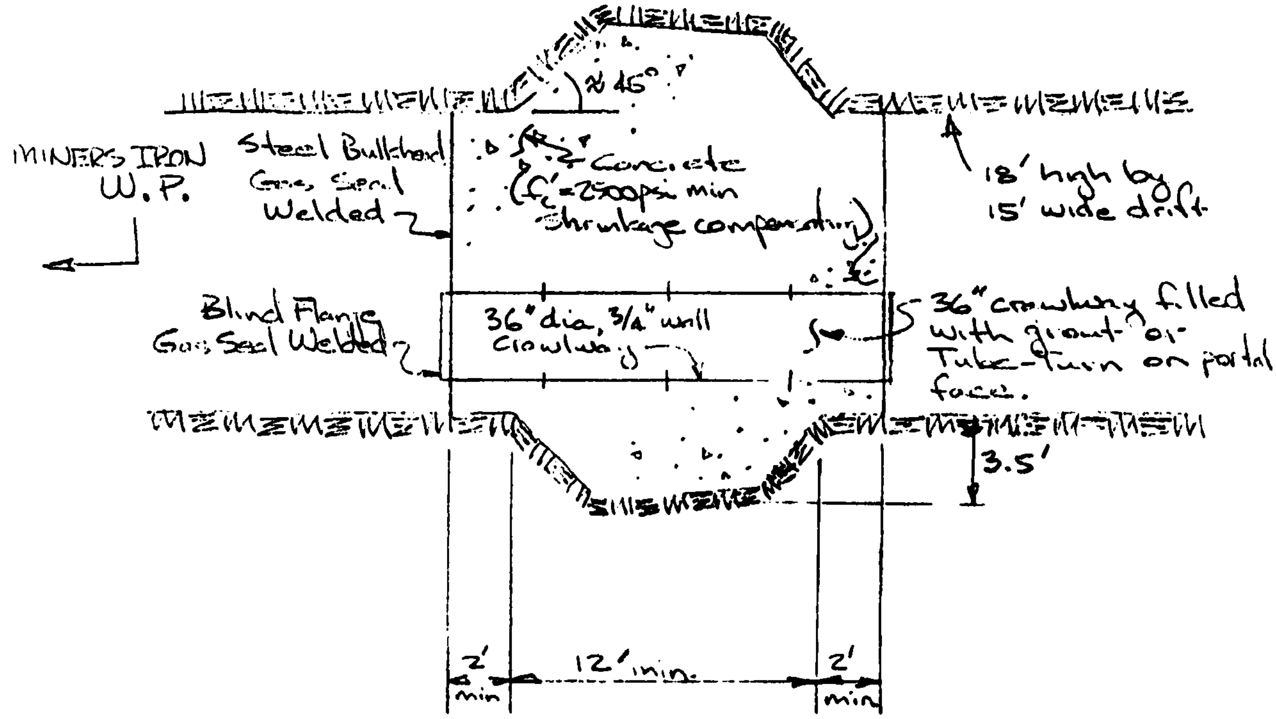
EDAC

BY SAS DATE 5/4/79 PROJECT DNA (MINERS IRON) PAGE 1 OF 1
CHKD. BY ______ DATE ______ SUBJECT U12n.03 OBP JOB NO. 177-010

MINERS IRON U12n.03 Overburden Plug



Elevation View

Notes.

1. All penetrations should have a minimum of 3 exterior gas block rings approximately equally spaced thru the plug length.
2. The 36" crawlway should have a minimum of 3 - 3 inch deep interior gas block rings approximately equally spaced thru the plug length.

MEMO

TO: Joe LaComb DATE: June 4, 1979

FROM: R. P. Kennedy

SUBJECT: MINERS IRON U12n.12 and U12n.03 Drift Overburden Plug

1. General

Design concepts of an overburden plug for the MINERS IRON event at three candidate sites are presented in this memo. These plug designs supersede designs previously submitted on May 4, 1979 and March 12, 1979. Due to the change in location of the MINERS IRON working point, the previous location of this plug in the U12n.03 is about 100 feet closer to the working point than previously. In addition, this tunnel is now oriented very close to the radial direction from the working point instead of at about a 50 degree angle. For these reasons the ground shock conditions are much more severe than they were for the previous working point location.

In the memo, plug designs capable of withstanding ground shock and 1000 psi and 1000°F pressure and temperature are presented for three potential sites for the purposes of cost estimation and final design. The locations considered are:

1. U12n.03 drift, portal face of plug at CS 20 + 86.

2. U12n.03 drift, portal face of plug at CS 19 + 16.

3. U12n.12 drift between CS 2 + 50 and CS 3 + 00.

The first location in the U12n.03 drift is at the end of the rehabed portion of this drift at a range of about 620 feet from the working point. The drift size at this location is highly variable and is as much as 18 feet high and 15 feet wide at some places. The second location in the U12n.03 drift is 170 feet further away from the working point along this drift. To construct the plug at this location the U12n.03 drift would have to rehabed for an additional 170 feet. For structural capacity calculations (pressure and ground shock loads), it is assumed that the drift size is the same as it is in the currently rehabed region of U12n.03 drift. The third location is in an adjacent 10 by 10 horseshoe shaped drift. At this location, the range from the working point is approximately 620 feet and the radial direction from the working point intersects the drift at an angle of about 50 degrees.

2. Minimum Plug Dimensions

Due to the large drift size of the U12n.03 drift, it is desirable to minimize additional mining and thus design concepts for friction-type overburden plugs have been provided and keyway-type plug designs are not considered. Design concepts for a plug located at CS 20 + 86 in the U12n.03 drift

are illustrated in Figure 1. Two alternatives are shown for the plug at this location. One alternative is a 42 foot long concrete plug with 5 small keyways (3 feet wide by 2 feet deep) along its length as shown in Figure 1a. The second alternative has 4 small keyways along its length but its length is 48 feet as shown in Figure 1b. In either case the plug is to be made of concrete with minimum unconfined compressive strength of 4000 psi and with as much positive expansion as it is currently possible to achieve (we understand that about 0.05 percent positive expansion is currently the upper limit).

A design concept for a friction-type plug located at CS 19 + 16 in the U12n.03 drift is illustrated in Figure 2. This concrete plug is 28 feet long with 3 small keyways. Concrete should have minimum unconfined compressive strength of 4000 psi and be positive expanding.

Two alternative design concepts for a plug to be located between CS 2 + 50 and CS 3 + 00 in the U12n.12 drift are illustrated in Figure 3. In Figure 3a, a 16 foot long keyway type plug with the key being 12 feet long and three feet deep is illustrated. In Figure 3b, a 23 foot long friction type plug with 3 small keyways is shown. For either design, concrete should have minimum unconfined compressive strength of 4000 psi. For the keyway plug, the concrete should be shrinkage compensating. For the friction plug, the concrete should be positive expanding. The plug dimensions shown in Figure 3 for the U12n.12 plug are based on there being a 10 foot thickness of superlean grout or similar material at the pressure loaded face of the plug. The strength of the superlean grout has been partially accounted for in determining plug dimensions and if this layer was not included in the design the dimensions in Figure 3 would have to be slightly larger.

Figures 1, 2 and 3 provide minimum plug dimensions needed to resist the design pressure and temperature and to assure that the plug moves integrally with the surrounding rock during ground shock.

3. Potential Bedding Plane Movement and Plug Design

Along the length of the U12n.12 drift there is a bedding plane which dips at about 15 degrees and intersects the upper portion of the drift. We have performed calculations for this bedding plane to predict differential movement from the MINERS IRON event in the same manner as was done for DIABLO HAWK as part of the MIGHTY EPIC/DIABLO HAWK block motion program. Using the same properties of friction and cohesion along the bedding plane as used for faults and bedding planes in MIGHTY EPIC and DIABLO HAWK block motion calculations, it is computed that no differential movement will occur along this bedding plane during MINERS IRON. However, this "clay rich" bedding plane is known to collect water along its surface and may have experienced differential movement during an earlier event. As a result, the friction and cohesion along this bedding plane may be less than the values

for more typical faults or bedding planes. Using values for friction and cohesion which are conservative lower bounds, it is calculated that there might be as much as three feet of differential displacement. Thus, there is the possibility of movement along this bedding plane and even though we do not expect movement approaching 3 feet to occur, we are concerned about this possibility and the potential consequences to a plug located in the U12n.12 drift.

For the U12n.12 plug design shown in Figure 3, additional measures are recommended to improve plug performance in the event of differential movement along the bedding plane. For the U12n.12 plug designs, it is recommended that a 3/8 inch thick steel plate be installed within the plug as shown in Figure 4. This plate should be located along the bedding plane and extend for 2 feet on either side of the plane. The plate should be situated at the point of maximum keyway width at a location near the pressure loaded face and extend out to the rock as shown in Figure 4. The plate should be rough coated such that good bond is developed between it and the bottom portion of plug and greased such that little or no bond is developed between it and the upper portion of the plug. Finally, there should be 10 feet of superlean grout or other forgiving material at the pressure loaded face of the plug as shown in Figure 3.

The steel plate within the U12n.12 plug constructed in the manner described above should provide a barrier across the bedding plane even if differential movement occurs. It is anticipated that if this plug is loaded by high pressure gas that the pressure will force superlean grout along the ruptured bedding plane and reseal the plug when this grout is pushed up against the steel plate. Observations of block motion during MIGHTY EPIC and DIABLO HAWK indicate cases in which grout has been forced along fault planes due to ground squeeze pressures and thus this design approach is considered to provide a leaktight barrier.

4. Other Plug Design Considerations

It is planned to have a 36 inch diameter, 3/4 inch wall thickness crawlway pipe penetrating the plug. This crawlway will be sealed at the pressure loaded face by a blind flange gas seal welded to it. In addition, the crawlway will have redundant gas blockage. If the plug is located in the U12n.03 drift, redundant gas blockage is provided by either placing a Tube-Turn at the portal end or by filling the crawlway with grout and providing three 3-inch deep gas block rings inside the crawlway as well as a portal face blind flange. If the plug is in the U12n.12 drift, the crawlway must be filled with grout as the effects of differential movement on an open crawlway pipe are not easily predicted. For a plug in the U12n.12 drift, it is important to locate the crawlway and any other penetrations such that they do not cross the bedding plane.

The crawlway and any other penetrations should be located following conventional clearance guidelines (1 foot 3 inches minimum clearence between crawlway and rockline) and should have a minimum of 3 exterior gas block rings approximately equally spaced through the length of the plug. The pressure loaded face of the plug should be covered by a steel bulkhead which is gas seal welded to be a leaktight barrier in the normal manner. The bulkhead on the pressure side used to construct the concrete portion of the plug in U12n.12 drift should be a steel bulkhead or, if a wood bulkhead is used, should be removed prior to placing the superlean grout. A steel bulkhead should be on the pressure loaded face of the superlean grout.

5. Summary and Conclusions

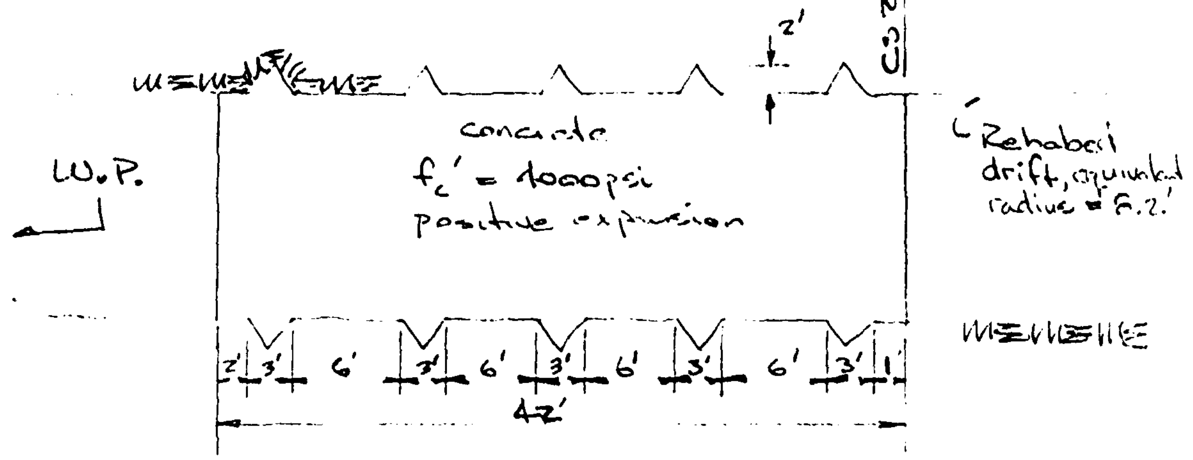
Five plug designs at three candidate locations have been presented in this memo for the purposes of cost estimation and the selection of a final design. The plugs for the U12n.03 drift have been designed in a manner consistent with the design of overburden plug containment structures for MINERS IRON and past events. The plug designs located in the U12n.12 drift appear to be less costly than the U12n.03 drift plug designs but represent somewhat greater risk due to the presence of the bedding plane which intersects this plug. We are concerned about the possibility of differential bedding plane movement through the U12n.12 drift plug.

EDAC

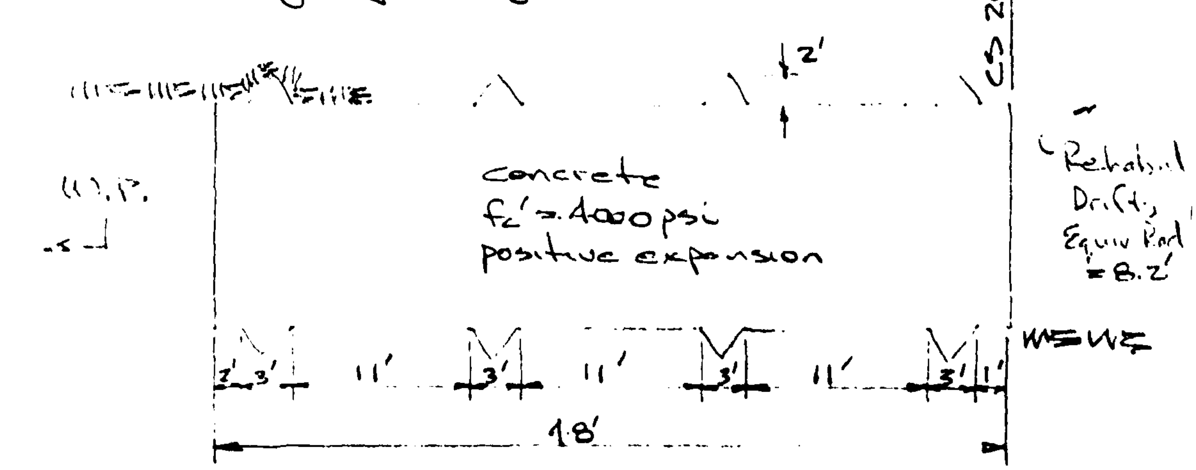
BY_______ DATE_______ PROJECT DNA/MINERAL IRON PAGE 1 OF 4
CHKD. BY_______ DATE_______ SUBJECT_______ JOB NO. 177-010

U12n.03 Plug — Portal face @ CS20+86

a. 5-keyway design



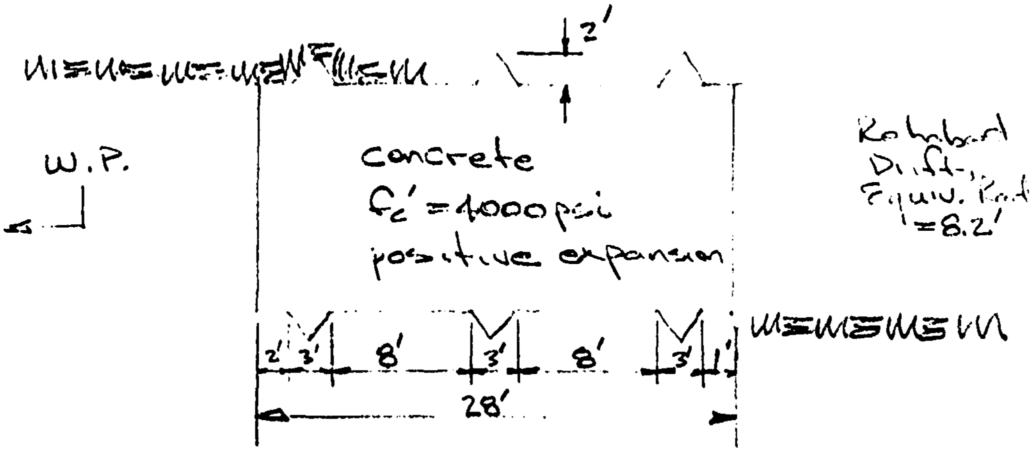
b. 4-keyway design



EDAC

BY ________ DATE ________ PROJECT DNA/MINE[illegible] PAGE 2 OF 4
CHKD. BY ________ DATE ________ SUBJECT ________ JOB NO. 177-010

U12n.03 Plug - Portal face @ CS 19+16



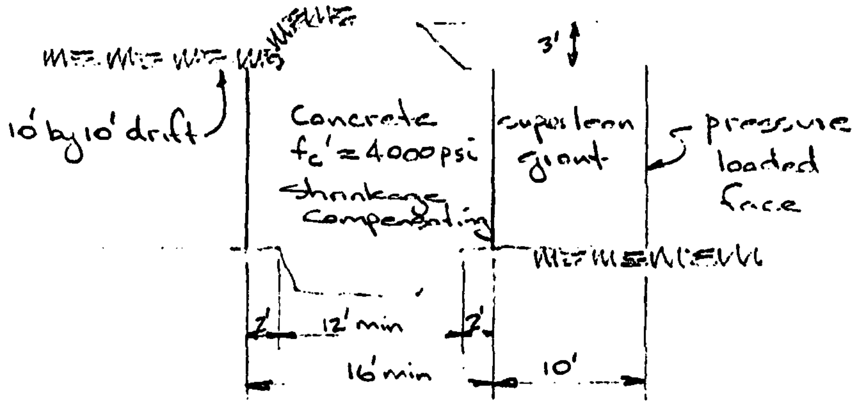
EDAC

BY ____ DATE ____ PROJECT DNA/MINUTEMAN PAGE 3 OF 4

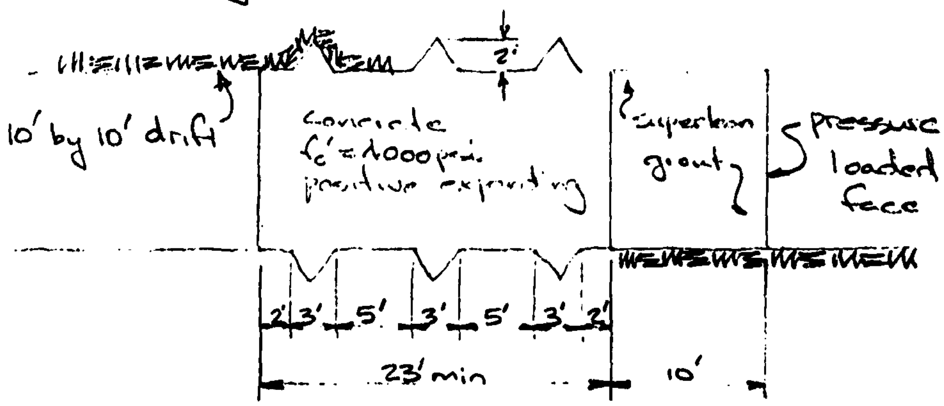
CHKD. BY ____ DATE ____ SUBJECT ____ JOB NO. 177-040

U12n.12 Drift Plug – Between CS 2+50 and 3+00

a. Keyway Plug



b. Friction Plug



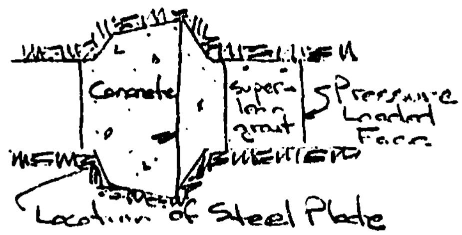
EDAC

BY ____ DATE ____ PROJECT DNA/MIDDLE [illegible] PAGE 4 OF 4

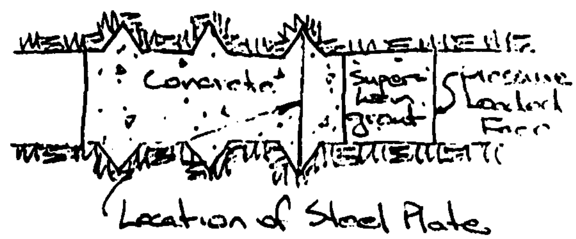
CHKD. BY ____ DATE ____ SUBJECT ____ JOB NO. 177-010

Plug Design Measures for Bedding Plane Movement

a) Plan View

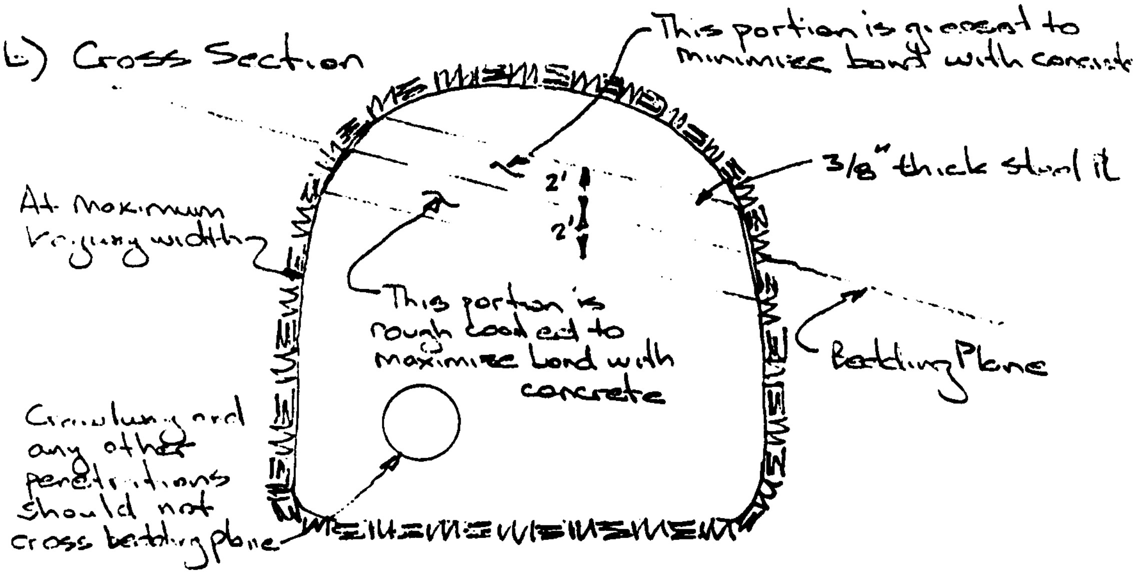


Keying Plug



Friction Plug

b) Cross Section



8. HURON KING LOS PIPE AND CONTAINMENT STRUCTURES

HURON KING is a vertical line-of-sight event for which EDAC provided various consulting support. EDAC suggested that an improved and less costly LOS pipe design could be achieved by using readily available gas and liquid fuel transmission pipe rather than fabricating the necessary pipe sections out of A-36 steel. Pipe stock lists from several sources were submitted to indicate current pipe availability. Also, EDAC participated in the design of the shock mounting of a large tank which will house experiments for the HURON KING. However, EDAC examined the shock mounting of this tank in a horizontal LOS pipe configuration as a possible alternative to the vertical LOS HURON KING event considered at the time. Finally, EDAC provided design sketches of a concrete collar at the top of the HURON KING drill hole which protects LOS pipe valves above by preventing downward movement of the LOS pipe relative to the surrounding soil.

The following reports document the EDAC effort on the HURON KING LOS pipe and containment structures.

- Vertical LOS Pipe, January 15, 1979, Page 8-3.

- Pipe Availability for Vertical Line-of-Sight Event, January 16, 1979, Page 8-5.

- Readily Available Pipe Sections, January 24, 1979, Page 8-9.

- Shock Mounting of a Large Tank, March 19, 1979, Page 8-17.

- Valve Protection Collar at the Top of the HURON KING Drill Hole, July 16, 1979, Page 8-19.

EDAC MEMO EDAC 177-040

TO: J. LaComb

FROM: R. P. Kennedy RPK DATE: January 15, 1979

SUBJECT: Vertical LOS Pipe

It is my understanding that on the vertical line-of-sight event, the portion of the LOS pipe between the muffler and the ground surface (about 800 feet) will consist of cylindrical pipe sections of unequal diameter in order to stepwise form a conical pipe. The maximum pipe diameter is about one meter at the ground surface. I understand that it is tentatively contemplated to fabricate these pipe sections out of A-36 steel. I would like to suggest an alternate which I believe will result in greater yield strength, greater ductility, and probably less expensive pipe sections.

I recommend the LOS pipe above the muffler be fabricated using standard readily available gas and liquid fuel transmission pipe of the type used on most major oil and gas pipelines. Sections of each pipe are readily available and have stringent quality control requirements on yield strength, ductility (elongation capacity), and weldability. Use of "off-the-shelf" pipe sections eliminates the need to fabricate your own pipe and will provide better quality pipe from the standpoint of ductility.

I suggest that you consider using API-5LX pipe as this pipe has been shown to have high ductility (better than A36). This pipe comes in several grades (X42, X46, X52, X56, X60, X65, X70) with the grade number representing the yield strength (ksi) of the steel. Grades X42 and X52 are readily available while the higher yield strength steels are less readily available. I believe X52 has certainly a high enough yield strength (52,000 psi) for your application and that even X42 is likely to be sufficient (42,000 psi yield strength). For ease of weldability, I do not recommend mixing pipe of different grades. Readily available pipe diameters in the range of interest are 16, 18, 20, 24, 30, 36 and possibly 40 inches.

pricing pg 6

In these diameters, wall thicknesses up to 0.375 inches are easily available and wall thicknesses up to 0.5 inches are probably available. I would tentatively recommend the following:

Range Station (distance in meters from device)	Diameter (inches)	Thickness (inches)	Pipe Grade
RS 89 - RS 141	20	0.25	API 5LX-52
RS 141 - RS 187	24	0.25	API 5LX-52
RS 187 - RS 244	30	0.312	API 5LX-52
RS 244 - RS 322	36	0.375	API 5LX-52

This represents a minimum number of changes of pipe diameter so as to maximize the length of pipe which can be welded together using standard pipeline welding techniques. Each diameter change is made where a value is inserted into the pipe string. These pipe thicknesses and grades are sufficient to withstand an internal pressure of 1,000 psi when backed by sand. Also, I believe these thicknesses are sufficient to prevent separation of the pipe above RS 89 as a result of downdrag from cavity collapse.

Holmes & Narver, through their sister company Williams Brothers Engineering, should be able to provide you with greater details on the availability of these pipe sections.

RPK:lca

EDAC MEMO EDAC 177-040

TO: J. LaComb

FROM: R. P. Kennedy

DATE: January 16, 1979

SUBJECT: Pipe Availability for Vertical Line of Sight Event

In a memo to you dated January 15, 1979, I suggested that the LOS pipe between the muffler and the ground surface, for the vertical line-of-sight event, be fabricated from "off the shelf" pipe sections. Attached is a pipe stock list from Kaiser Steel. This list indicates the pipe diameters and wall thicknesses which are available for immediate shipment from this fabricator.

RPK:SAS:lca

DATE JANUARY 15, 1979 NO 70

KAISER STEEL

PIPE STOCK LIST

THIS STOCK IS AVAILABLE AT FONTANA, CALIFORNIA
AND IS OFFERED SUBJECT TO PRIOR SALE

THIS LIST SUPERSEDES ALL PREVIOUS STOCK LISTS

ERW

5-9/16" - 16" O.D.
BLACK PLAIN ENDS

ALL PIPE UNCOATED
UNLESS MARKED "X"

FUTURE AVAILABILITIES

12-3/4"	JANUARY
5-9/16"	JANUARY
6-5/8"	FEBRUARY
8-5/8"	FEBRUARY
10-3/4"	MARCH
16"	MARCH

O.D. SIZE	WALL	WEIGHT PER FOOT	QUANTITY FOOTAGE	TONS
6-5/8"	.156	10.78	4585	25
	.188	12.92	626	4
	.219	14.98	4070	29
	.250	17.02	17810	152
	.280	18.97	12944	123
8-5/8"	.156	14.11	22039	155
	.172	15.33	18045	140
	.188	16.94	22499	190
	.203	18.26	1500	14
	.219	19.66	4470	44
	.250	22.36	18912	214
	.277	24.70	7201	89
	.322	28.55	2810	40
10-3/4"	.188	21.21	115	1
	.219	24.63	19063	235
	.250	28.04	14117	197
	.279	31.20	18206	284
	.307	34.24	768	13

O.D. SIZE	WALL	WEIGHT PER FOOT	QUANTITY FOOTAGE	TONS
10-3/4"	.365	40.48	14487	293
12-3/4"	.188	25.22	16125	203
	.219	29.31	12409	187
	.250	33.38	14123	236
	.281	37.42	880	16
	.312	41.45	544	11
	.330	43.77	2131	47
14"	.188	27.73	2970	41
	.219	32.23	6780	109
	.250	36.71	3507	64
	.312	45.61	1101	25
16"	.188	31.75	18626	296
	.219	36.91	18289	338
	.236	39.73	3036	60
	.250	42.05	9954	209
	.281	47.17	3490	88
	.312	52.27	5002	131
	.375	62.58	3802	119

THE FOLLOWING PIPE IS AVAILABLE AT NAPA, CALIFORNIA FOR IMMEDIATE SHIPMENT SUBJECT TO PRIOR SALE

SAW

16" - 42" O.D.
BLACK PLAIN ENDS

ALL PIPE UNCOATED
AND UNLINED UNLESS
MARKED w/"C" or "L"

PLANNED ROLLINGS

18"	FEB/MARCH
20"	MARCH
24"	MARCH
30"	MARCH
36"	MARCH

O.D. SIZE	WALL	WEIGHT PER FOOT	QUANTITY FOOTAGE	TONS
16"	.375	62.58	7861	246
	.438	72.80	11573	421
	.500	82.77	6717	278
	.625	102.63	1576	81
18"	.312	58.94	157	5
	.375	70.59	3801	134
	.438	82.15	160	7
	.500	93.45	7900	369
	.688	127.21	240	15
20"	.250	52.73	119	3
	.281	59.18	3251	96
	.312	65.60	932	31
	.375	78.60	512	20
	.438	91.51	8916	408
	.469	97.83	511	25
	.500	104.13	4053	211
	.688	141.90	749	53
	.750	154.19	5373	414
21-1/4"	.625	137.67	894	61
22"	.312	72.27	119	4
	.375	86.61	8444	366

O.D. SIZE	WALL	WEIGHT PER FOOT	QUANTITY FOOTAGE	TONS
22"	.500	114.81	1750	100
	.562	128.67	278	18
	.625	142.68	200	14
	.688	156.60	209	16
24"	.250	63.41	5988	190
	.281	71.18	1210	43
	.375	94.62	950	45
	.438	110.22	568	31
	.500	125.49	2588	162
	.562	140.68	316	22
	.625	156.03	1617	126
	.875	216.10	396	42
26"	.250	68.75	4289	147
	.375	102.63	6350	326
	.500	136.17	5660	385
	.625	169.38	2170	184
	.750	202.25	2850	288
28"	.375	110.64	2564	142
	.500	148.65	1600	119
	.625	182.73	3803	347
	.750	218.27	1300	142

CW PIPE ¾" - 4", OVER PLEASE →

DATE	JANUARY 15, 1979	NO. 70

KAISER STEEL

PIPE STOCK LIST

THIS STOCK IS AVAILABLE AT **FONTANA**, CALIFORNIA
AND IS OFFERED SUBJECT TO PRIOR SALE

THIS LIST SUPERSEDES ALL PREVIOUS STOCK LISTS

ERW

5-9/16" - 16" O.D.
BLACK PLAIN ENDS

ALL PIPE UNCOATED
UNLESS MARKED "X"

O.D. SIZE	WALL	WEIGHT PER FOOT	QUANTITY FOOTAGE	TONS	O.D. SIZE	WALL	WEIGHT PER FOOT	QUANTITY FOOTAGE	TONS

THE FOLLOWING PIPE IS AVAILABLE AT **NAPA**, CALIFORNIA FOR IMMEDIATE SHIPMENT SUBJECT TO PRIOR SALE

SAW

16" - 42" O.D.
BLACK PLAIN ENDS

ALL PIPE UNCOATED
AND UNLINED UNLESS
MARKED w/"C" or "L"

O.D. SIZE	WALL	WEIGHT PER FOOT	QUANTITY FOOTAGE	TONS	O.D. SIZE	WALL	WEIGHT PER FOOT	QUANTITY FOOTAGE	TONS
30"	.281	89.19	571	25					
	.312	98.92	154	8					
	.375	118.65	2600	154					
	.500	157.53	1600	129					
	.625	196.08	2810	275					
	.750	234.29	2962	347					
	.875	272.17	383	52					
	1.000	309.72	1385	214					
34"	.375	134.67	117	8					
	.438	157.00	233	18					
36"	.312	118.92	729	43					
	.334	127.22	730	47					
	.344	131.00	1992	130					
	.375	142.68	3877	277					
	.500	189.57	7044	688					
	.625	236.13	2440	288					
	.750	282.35	2345	331					
	1.000	373.80	3543	662					

CW PIPE ¾" - 4", OVER PLEASE ⟶

KAISER STEEL — PIPE STOCK LIST

THIS STOCK IS AVAILABLE AT FONTANA, CALIFORNIA
AND IS OFFERED SUBJECT TO PRIOR SALE

CW

¾" – 4" (NOM.)

3½" – 4½" O.D.
X .188" WALL

BLACK PIPE

STANDARD & EX. STR.
PE & T & C

ALL PIPE 21' U/L
UNLESS MARKED
D-R/L

SIZE	WEIGHT	COATING	QUANTITY FOOTAGE	TONS
3/4"	STD T&C	CTD	19,320	11
	STD PE	UNC	620,928	351
	STD PE	CTD	298,117	168
	XS PE	UNC	88,642	65
	XS PE	CTD	47,627	35
1"	STD T&C	CTD	16,380	14
	STD PE	CTD	70,560	60
	XS PE	UNC	93,555	101
	XS PE	CTD	945	1
1-1/4"	STD T&C	UNC	14,112	16
	STD T&C	CTD	54,725	104
	STD PE	UNC	194,040	220
	STD PE	CTD	116,188	132
	XS PE	UNC	29,106	44
	XS PE	CTD	2,672	4°
	XS PE	CTD	83,160	124
1-1/2"	STD T&C	CTD	84,672	116
	STD PE	UNC	359,856	490
	STD PE	CTD	182,196	248
	XS PE	UNC	13,041	24
	XS SC	UNC	4,536	8°
	XS SC	CTD	2,268	4°
2"	STD T&C	CTD	50,050	92
	STD PE	UNC	3,528	6
	STD PE	UNC	126,878	232*
	STD PE	CTD	137,046	250
	XS PE	UNC	59,451	149
	XS PE	CTD	7,980	20
	STD SC	UNC	37,488	68°
2-1/2"	STD T&C	CTD	25,436	85
	STD PE	UNC	56,952	164
	STD PE	CTD	31,374	91
	STD SC	CTD	28,200	81°

SIZE	WEIGHT	COATING	QUANTITY FOOTAGE	TONS
3"	STD T&C	CTD	1,764	7
	STD PE	UNC	45,546	170
	STD SC	UNC	2,352	9
	STD PE	CTD	36,456	137
	XS SC	UNC	4,060	20°
	XS SC	CTD	5,075	26°
3-1/2"	STD T&C	CTD	3,234	16
	STD PE	UNC	44,814	204
	STD PE	CTD	16,632	74
	XS PE	CTD	5,880	37
	XS SC	CTD	17,496	109°
4"	STD T&C	UNC	4,950	26
	STD PE	CTD	4,620	25
	STD PE	UNC	13,860	75
3-1/2"	188 PE	UNC	16,947	56
	188 PE	UNC	3,192	11*
	188 PE	CTD	945	3
4-1/2"	188 PE	UNC	40,698	176*
	188 PE	UNC	6,018	26

FUTURE AVAILABILITIES

SIZE	
2"	12/24
2-1/2"	1/28
2"	2/4
1"	2/11

° 20'3" + - 3"
* DOUBLE RANDOM LENGTHS

Thanks for Supporting
AMERICAN STEEL / AMERICAN JOBS

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EDAC 177-040

TO: J. LaComb DATE: 24 January 1979

FROM: R. P. Kennedy RPK

SUBJECT: Readily Available Pipe Sections

Attached is additional information on "off the shelf" pipe sections which might be used for the vertical line-of-sight event (see EDAC memo to J. LaComb dated January 15, 1979).

EDAC

Gulf Fabricating & Supply
Suite 225, Vieux Carré Building
3223 Smith Street
Houston, Texas 77006

RECEIVED
A10:59

PHONE..... 1-713-523-1674

STOCK LIST

LINE PIPE

OD	WALL	WT/FT	SPEC	FT
2-3/8 "	.154	3.65	A53B	800
" "	.218	5.02	A106B	52,236
" "	.344	7.46	A106B	412
" "	.436	9.03	A106B	200
2-7/8 "	.203	5.79	A53B	777
" "	.276	7.66	A106B	167
3-1/2 "	.188	5.57	API5LX42	1,274
" "	.216	7.58	A106B	18,493
" "	.300	10.25	A53B & A106B	4,719
" "	.600	18.58	A106B	360
4 "	.226	9.11	A106B	170
" "	.318	12.50	A106B	209
4-1/2 "	.188	8.66	API5LX42	1,279
" "	.237	10.79	A53B & A106B	6,300
" "	.337	14.98	A53B	198
" "	.531	22.51	A106B	80
5-9/16"	.258	14.62	A53B	73
" "	.375	20.78	A53B	3,138
6-5/8 "	.188	12.92	API5LX42	890
" "	.219	14.98	API5LX42	328
" "	.280	18.97	API	531
" "	.432	28.57	A106B	272
8-5/8 "	.250	22.36	API5LX42	194
" "	.277	24.70	API5LX42	489
" "	.322	28.55	A53B	316

OD	WALL	WT/FT	SPEC	FT
8-5/8 "	.500	43.39	A106B	687
" "	.500	43.39	API5LX52	1,841
10-3/4 "	.250	28.03	API5LX42	395
" "	.365	40.48	A106B	1,333
" "	.365	40.48	API5LX60	120
" "	.500	54.74	API5LX52	995
12-3/4 "	.250	28.03	API5LX42	743
" "	.330	43.77	API5LB	621
" "	.375	49.56	API5LX52	384
" "	.500	65.42	A106B	101
14	.375	54.57	A106B	1,113
" "	.500	72.09	A53B	240
16 "	.250	42.05	API5LB	1,147
" "	.375	62.58	A53B	309
" "	.500	82.77	API5LX52	680
" "	.844	136.46	A106B	102
18 "	.312	58.94	API5LX42	294
" "	.375	70.59	API5LB	-0-
" "	.500	93.45	API5LX52	1,526
" "	.562	104.67	A106B	121
" "	.750	138.17	A106B	54
" "	.938	170.75	A106B	58
20 "	.250	52.73	API5LB	192
" "	.281	59.18	API5LX52	564
" "	.312	65.60	A53B	109
" "	.375	78.60	A53B	211
" "	.438	91.51	API5LX52	12,375
" "	.469	97.83	A252 II	507
" "	.500	104.13	API5LX52	3,984
" "	.594	123.11	A106B	379
" "	.625	129.33	API5LX52	1,822
22 "	.500	114.81	API5LX52	377
24 "	.312	78.93	API5LB	229
" "	.375	94.62	API5LX42	83
" "	.500	125.49	API5LX52	2,000
" "	.969	296.58	A106B	40
26 "	.375	102.63	API5LB	192
" "	.500	136.17	API5LX52	3,024
30 "	.375	118.65	API5LB	89
" "	.500	157.53	API5LX52	24

OD		WALL	WT/FT	SPEC	FT
30	"	.625	196.08	API 5LB	207
"	"	1.000	309.72	API 5LX42	600
"	"	1.000	309.72	API 5LX52	166
"	"	1.500	456.57	API 5LX42	244
36	"	.375	142.68	API 5LX42	83
"	"	.500	189.57	API 5LX42	1,008
"	"	1.000	374.00	GRADE B	- 0 -
"	"	1.250	464.31	GRADE B	500
42	"	.375	166.71	API 5LB	124
"	"	.500	221.61	API 5LB	81
"	"	1.000	438.00	GRADE B	800
"	"	1.250	491.00	GRADE B	400
48	"	.375	190.74	API 5LB	204
"	"	.500	253.41	API 5LB	39
"	"	1.250	624.00	GRADE B	200

STOCK AT FEBRUARY 01, 1978

SUBJECT TO PRIOR SALE

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Pipe

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We have recently completed the inventory of our St. Louis yard facility and are pleased to offer the following excess inventory listing of domestically manufactured seamless tubular products:

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5,000'	2 3/8" O.D., .218 WT, DRL, A106, Grade B
3,000'	3 1/2" O.D., .216 WT, SRL, A53, Grade B
2,000'	3 1/2" O.D., .300 WT, DRL, A106, Grade B
620'	3 1/2" O.D., .600 WT, DRL, A106, Grade B
1,550'	4 1/2" O.D., .237 WT, SRL, A53, Grade B
3,400'	4 1/2" O.D., .237 WT, SRL, A106, Grade B
2,000'	4 1/2" O.D., .337 WT, DRL, A106, Grade B
2,000'	6 5/8" O.D., .280 WT, DRL, A106, Grade B
1,050'	8 5/8" O.D., .250 WT, DRL, A53, Grade B
1,000'	8 5/8" O.D., .322 WT, DRL, A106, Grade B
1,000'	10 3/4" O.D., .365 WT, DRL, API5L, Grade B
880'	10 3/4" O.D., .500 WT, DRL, A106, Grade B
1,820'	12 3/4" O.D., .375 WT, DRL, A106, Grade B
660'	12 3/4" O.D., .688 WT, DRL, A106, Grade B
1,740'	14" O.D., .375 WT, DRL, A106, Grade B

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610'	14" O.D., .500 WT, DRL, A53, Grade B
500'	16" O.D., .375 WT, DRL, API5L, Grade B
500'	18" O.D., .375 WT, DRL, API5L, Grade B
430'	18" O.D., .500 WT, DRL, A106, Grade B
550'	20" O.D., .375 WT, DRL, API5L, Grade B
700'	20" O.D., .500 WT, DRL, A53, Grade B
380'	22" O.D., .375 WT, DRL, A53, Grade B
400'	24" O.D., .375 WT, DRL, A106, Grade B
128'	24" O.D., .688 WT, DRL, A106, Grade B

The following represents our excess inventory in domestic DSAW tubulars:

390'	30" O.D., .375 WT, DRL, API5L, Grade B
440'	30" O.D., .500 WT, DRL, API5L, Grade B
384'	36" O.D., .375 WT, DRL, API5L, Grade B
670'	42" O.D., .375 WT, DRL, API5L, Grade B

All materials on this listing are subject to prior sale. All items are immediately available for your inspection, and original mill test reports are provided. All items are quoted F.O.B. St. Louis, Missouri.

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Sincerely,

PIPECO AMERICA, LTD.

pipeco america, ltd.

March 23, 1977

Williams Brothers
Resource Science Group
6600 South Yale Avenue
Tulsa, Oklahoma 74136

Attention: Mr. Ray Holder

Dear Mr. Holder:

Pipeco America, Ltd. is a tubular products distributor for many domestic and foreign steel mills. Our services include the supply of seamless and welded carbon steel pipe from 2 3/8" O.D. through 60" O.D., pressure piping 1 1/2" and under, a full line of valves, flanges, and fittings, and complete fabrication services (including special castings, cutting, beveling, coating and wrapping). We also stock and distribute domestically manufactured square and rectangular tubular products and beams.

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Please let us help you with your requirements and take the unknown elements out of dealing with less qualified suppliers.

Sincerely,

PIPECO AMERICA, LTD.

Bernice

Bernice Pennington

BP/sy

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RED FIGURES
Wall Thickness
in Inches

WEIGHTS AND DIMENSIONS OF SEAMLESS AND WELDED PIPE

BLUE FIGURES
Weight Per Foot
in Pounds

PIPE SIZE	O. D. In Inches	A. S. A. PIPE SCHEDULES 5	10	20	30	40	STD.	60	80	E. H.	100	120	140	160	DBLE. E.H.
1/8	.405	.035 .1383	.049 .1863			.068 .2447	.068 .2447		.095 .3145	.095 .3145					
1/4	.540	.049 .2570	.065 .3297			.088 .4248	.088 .4248		.119 .5351	.119 .5351					
3/8	.675	.049 .3276	.065 .4235			.091 .5676	.091 .5676		.126 .7388	.126 .7388					
1/2	.840	.065 .5383	.083 .6710			.109 .8510	.109 .8510		.147 1.088	.147 1.088				.187 1.304	.294 1.714
3/4	1.050	.065 .6838	.083 .8572			.113 1.131	.113 1.131		.154 1.474	.154 1.474				.218 1.937	.308 2.441
1	1.315	.065 .8678	.109 1.404			.133 1.679	.133 1.679		.179 2.172	.179 2.172				.250 2.844	.358 3.659
1¼	1.660	.065 1.107	.109 1.806			.140 2.273	.140 2.273		.191 2.997	.191 2.997				.250 3.765	.382 5.214
1½	1.900	.065 1.274	.109 2.085			.145 2.718	.145 2.718		.200 3.631	.200 3.631				.281 4.859	.400 6.408
2	2.375	.065 1.604	.109 2.638			.154 3.653	.154 3.653		.218 5.022	.218 5.022				.343 7.444	.436 9.029
2½	2.875	.083 2.475	.120 3.531			.203 5.793	.203 5.793		.276 7.661	.276 7.661				.375 10.01	.552 13.70
3	3.500	.083 3.029	.120 4.332			.216 7.576	.216 7.576		.300 10.25	.300 10.25				.437 14.32	.600 18.58
3½	4.000	.083 3.472	.120 4.973			.226 9.109	.226 9.109		.318 12.51	.318 12.51					.636 22.85
4	4.500	.083 3.915	.120 5.613			.237 10.79	.237 10.79	.281 12.66	.337 14.98	.337 14.98		.437 19.01		.531 22.51	.674 27.54
4½	5.000						.247 12.53			.355 17.61					.710 32.53
5	5.563	.109 6.349	.134 7.770			.258 14.62	.258 14.62		.375 20.78	.375 20.78		.500 27.04		.625 32.96	.750 38.55
6	6.625	.109 7.585	.134 9.289			.280 18.97	.280 18.97		.432 28.57	.432 28.57		.562 36.39		.718 45.30	.864 53.16
7	7.625						.301 23.57			.500 38.05					.875 63.08
8	8.625	.109 9.914	.148 13.40	.250 22.36	.277 24.70	.322 28.55	.322 28.55	.406 35.64	.500 43.39	.500 43.39	.593 50.87	.718 60.93	.812 67.76	.906 74.69	.875 72.42
9	9.625						.342 33.90			.500 48.72					
10	10.750	.134 15.19	.165 18.70	.250 28.04	.307 34.24	.365 40.48	.365 40.48	.500 54.74	.593 64.33	.500 54.74	.718 76.93	.843 89.20	1.000 104.1	1.125 115.7	
11	11.750						.375 45.55			.500 60.07					
12	12.750	.165 22.18	.180 24.20	.250 33.38	.330 43.77	.406 53.53	.375 49.56	.562 73.16	.687 88.51	.500 65.42	.843 107.2	1.000 125.5	1.125 139.7	1.312 160.3	
14	14.000		.250 36.71	.312 45.68	.375 54.57	.437 63.37	.375 54.57	.593 84.91	.750 106.1	.500 72.09	.937 130.7	1.093 150.7	1.250 170.2	1.406 189.1	
16	16.000		.250 42.05	.312 52.36	.375 62.58	.500 82.77	.375 62.58	.656 107.5	.843 136.5	.500 82.77	1.031 164.8	1.218 192.3	1.437 223.5	1.593 245.1	
18	18.000		.250 47.39	.312 59.03	.437 82.06	.562 104.8	.375 70.59	.750 138.2	.937 170.8	.500 93.45	1.156 208.0	1.375 244.1	1.562 274.2	1.781 308.5	
20	20.000		.250 52.73	.375 78.60	.500 104.1	.593 122.9	.375 78.60	.812 166.4	1.031 208.9	.500 104.1	1.280 256.1	1.500 296.4	1.750 341.1	1.968 379.0	
24	24.000		.250 63.41	.375 94.62	.562 140.8	.687 171.2	.375 94.62	.968 238.1	1.218 296.4	.500 125.5	1.531 367.4	1.812 429.4	2.062 483.1	2.343 541.9	

EDAC MEMO 177-040

TO: Joe LaComb DATE: March 19, 1979

FROM: R. P. Kennedy

SUBJECT: Shock Mounting of a Large Tank

This memo is sent in order to document information presented orally to you at a meeting on February 8, 1979. The purpose of our effort was to provide data to be used in reaching a decision on siting of the large tank.

Design concepts for limiting the acceleration of a large tank subjected to a ground shock environment of about 35g have been considered. This tank is 7 meters in diameter and 10 meters in length in a configuration similar to that illustrated on the attached figure. Tank weight is 200,000 pounds.

A concept for shock mounting the tank is illustrated on the attached figure. As shown in this figure, the tank is supported on 72 standard aluminum honeycomb blocks with 18 blocks at each of the four support points for the tank. Standard aluminum honeycomb blocks have dimensions of 11 inches by 13 inches by 18 inches high and have a crushing strength of 40 psi. Beneath the honeycomb blocks are plexiglas sheets which permit sliding of the tank during ground shock and thus limit horizontal accelerations. This concept should limit dynamic accelerations of the tank to under 2g. Crush of the honeycomb block is expected to be less than 4 inches. Note that a bellows must be designed to accommodate displacements between the tank and the LOS pipe connected to the tank. In order to prevent the LOS pipe from damaging the tank, the bellows must accommodate relative movements of 12 inches radially and 6 inches transversely and vertically.

For the aluminum honeycomb support system described above, the tank must have a support system which is capable of distributing the tank loads to the honeycomb blocks in a uniform manner. In addition, a means of tying the tank, support system and honeycomb blocks together must be designed to assure satisfactory behavior during lateral movement and possible jumping off the ground.

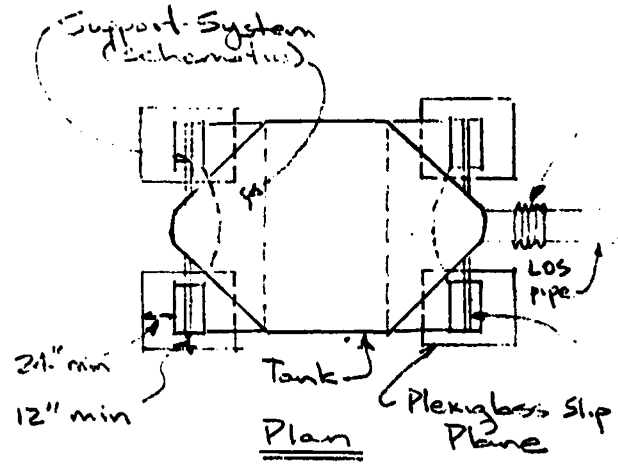
We also examined shock mounting concepts in which the tank was suspended from the back of the tunnel. For an item of this weight, these concepts all appear unfeasible.

EDAC

BY DAC DATE 3/15/77 PROJECT DNA PAGE 1 OF 1
CHKD. BY DATE SUBJECT Tank Shock Mounting JOB NO. 177-010

Aluminum Honeycomb System

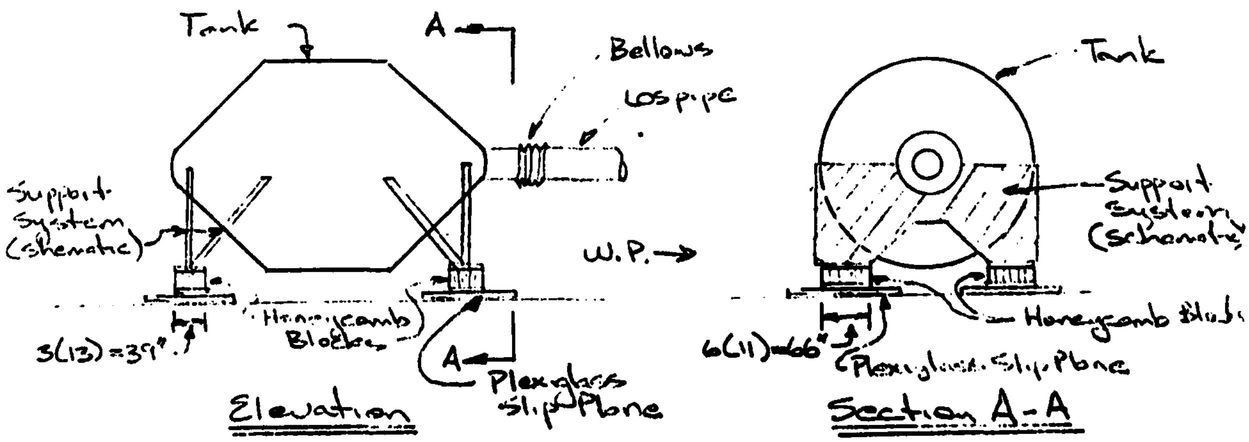
S10 Block = 11" by 13" by 18" hig
40 psi crush strength



Bellows must accommodate 12" longitudinal and 6" transverse and vertical relative displacements

W.P. →

18 Aluminum Honeycomb Blocks (Typical 4 places for a total of 72 blocks)



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MEMO

TO: Joe LaComb DATE: July 16, 1979

FROM: for R. P. Kennedy SAS

SUBJECT: Valve Protection Collar at the Top of the HURON KING Drill Hole

---

Attached is a design sketch for the collar to be located at 62" below the final grade for the HURON KING event. The purpose of this collar is to provide protection from a shear failure for the gas containment valves located above the top of the collar. The collar prevents the LOS pipe and the attached casings from moving downward relative to the surrounding soil after the HURON KING event and damaging the gas containment valves. The design load on the slab was calculated assuming that the slab must support the weight of the LOS pipe, the 74" steel casing, the 98" steel casing, all stemming material interior to the 74" casing, and some of the material exterior to the 74" casing to a depth of 950' below the ground surface. In calculating the weight of the material exterior to the 74" casing only the cohesive materials surrounding both the 74" and 98" casings were considered. Both the Monterey Sand and the coarse gravel were assumed to fall away from the casing into the surrounding cavity and therefore were not part of the overall load on the slab. The design load on the collar was calculated to be 7,900,000 lb. including a factor of safety of 1.5.

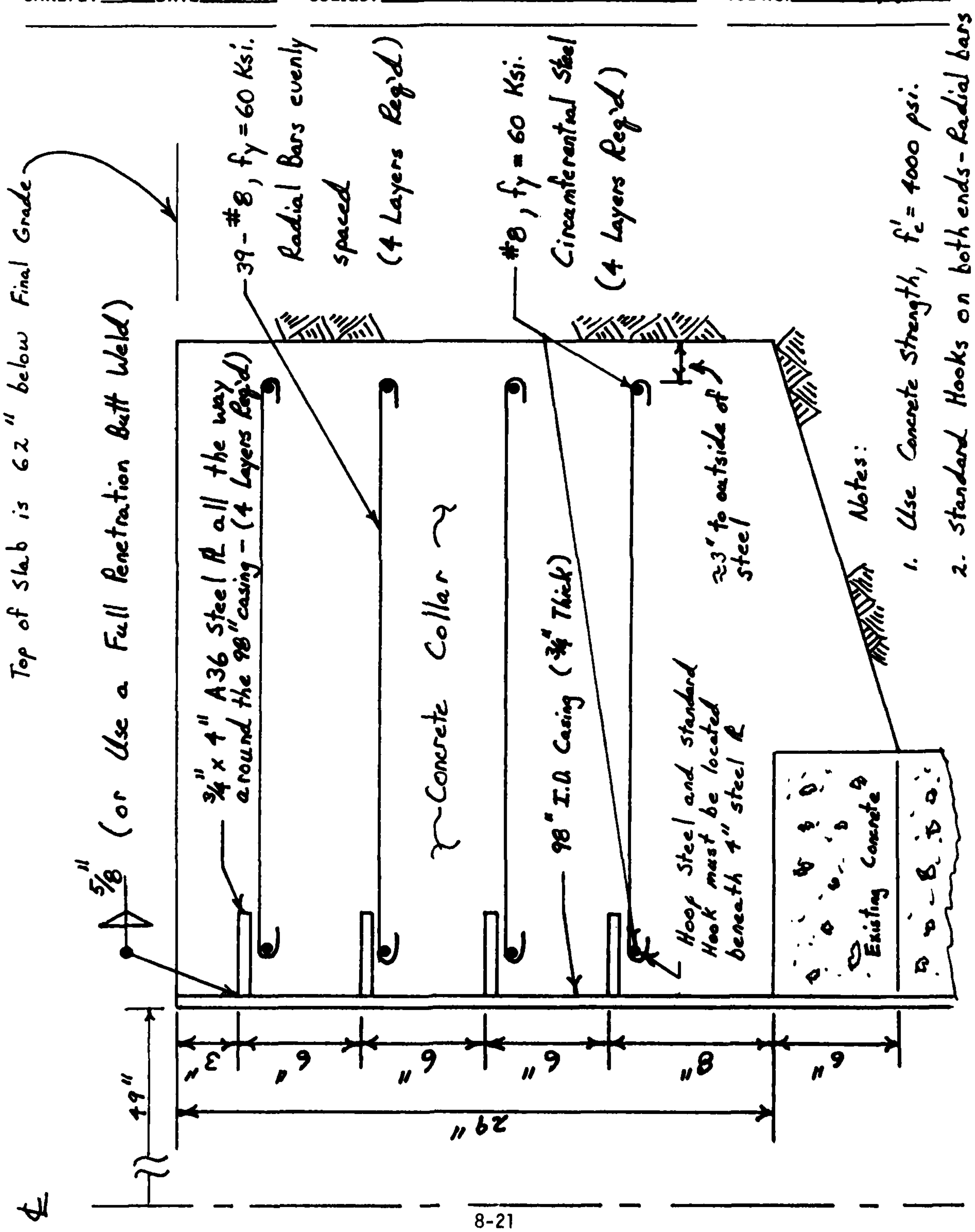
The design load was considered to be applied to the circumference of the 98" casing at the top of the collar by transferring the weight of the LOS pipe and surrounding stemming through the strongback to the top edge of the 98" casing. The concrete collar design presented in the accompanying sketch is able to withstand the design load through shear and flexural load paths within the collar to the surrounding soil without benefit of the existing concrete below the collar. This is a conservative approach since some of the load would be transferred through friction between the concrete and soil in the 117' of existing concrete exterior to the 98" casing. However, this load path was not accounted for because of the uncertainty in calculating the total percentage of load transferred in this fashion.

The attached sketch represents the minimum dimensions and reinforcing required to resist the design load in the conservative manner described above. The basic design is a circular concrete collar with an outside diameter of 156 inches and variable depth as shown on the attached sketch. In order to assure shear transfer between the 98" casing and the concrete collar, 4 sets of shear keys are required. Each set of shear keys consists of a 3/4" x 4" steel plate welded on both sides with a 5/8" fillet weld all the way around the circumference of the 98" casing. A full penetration butt weld may be used instead of the fillet weld. Four layers of radial reinforcing bars are required to prevent a punching type shear

failure. Each layer consists of 39 - #8 bars with standard hooks at each end evenly spaced around the 98" casing. The hooks on the radial steel must enclose the circumferential steel as shown in the sketch. At the base of the slab exterior to the existing concrete an additional 6" deep section at a slope of approximately 20° must be excavated in order to provide sufficient friction between the slab and the soil.

EDAC

BY RHK DATE 7/16/79 PROJECT Huron King Collar PAGE 1 OF 1
CHKD. BY ____ DATE ____ SUBJECT ____ JOB NO. 177-047



9. MISCELLANEOUS ITEMS

During the contract period, EDAC performed some miscellaneous tasks which were not associated with a particular event. These tasks included; 1) the conceptual design of a shock mounting system for instrumentation racks to be used for future events; 2) guidelines of the use of positive expanding and shrinkage compensating concrete and grout; and 3) recommendations for friction tests of shock mounting materials on plexiglas slip planes.

The following reports document the miscellaneous tasks.

- Shock Mounting of Instrumentation Racks, March 6, 1979, Page 9-3.
- Use of Positive Expanding and Shrinkage Compensating Concrete and Grout, March 19, 1979, Page 9-7.
- Recommendations for Friction Tests, March 19, 1979, Page 9-9.

EDAC

MEMO

TO: Joe LaComb DATE: March 6, 1979

FROM: for R. P. Kennedy SAS

SUBJECT: Shock Mounting of Instrumentation Racks

A conceptual design of a shock mounting system for instrumentation racks to be used for future events is presented here. This shock mounting is designed to limit rack accelerations to under 10g (for racks weighing between 550 and 1,150 lbs.) when subjected to a natural environment of as much as 60g. The shock mounting system discussed here is intended to provide versatility in locating instrumentation racks after the rack alcoves have been constructed. This versatility is achieved by constructing a grid of rock bolts in the back of the tunnel to be used for support of the racks. Invert supports for racks may be provided by redheads placed in the concrete floor of the rack alcove.

The design concept for shock mounting of instrumentation racks is a suspended configuration as shown in Figure 1. The suspended configuration is the most reliable method for rack shock mounting. For this configuration, racks are suspended from the back of the tunnel and tied to the invert by nylon ropes. These ropes must be inclined at an angle as defined by dimensions A and B in Figure 1.

Because instrumentation racks are commonly 2 or 3 feet wide and 2 feet deep, it is possible to support the racks directly from rock bolts in the back of the tunnel if rock bolts are spaced at 2.5 feet along the length of the rack alcove and at 2 feet across the alcove as shown in Figure 2. This grid of rock bolts provides some versatility in locating racks and, if needed, further versatility can be achieved by spanning channel beams between rock bolts and supporting the rack from some point along the channel. The use of redheads for tying nylon rope to the invert provides total flexibility for locating the racks. Back and invert supports should be designed for the following loads:

Tension	-	11 kips
Shear	-	3 kips

cc: A. C. Hollins - H&N, Area 12
LCDR Larsen - DNA, Mercury

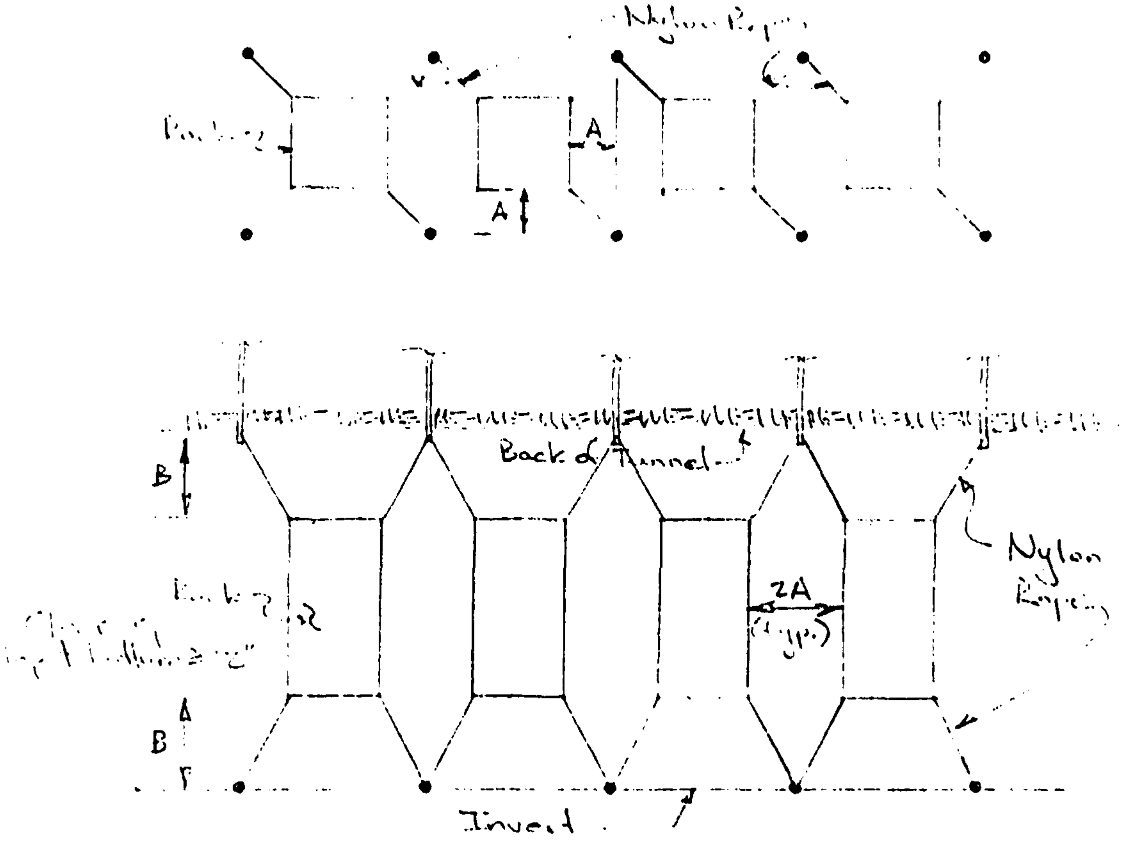
preceding page blank

EDAC

BY ______ DATE 2/7/79 PROJECT DNA PAGE 1 OF 2

CHKD. BY ______ DATE ______ SUBJECT Shock Mounting of Instrumentation Racks JOB NO. 177-040

A suspended configuration as shown below is most reliable. For rack weights of 550 to 1150 lbs in a natural environment of about 60g, the following configuration is adequate to limit rack accelerations to under 10g.



For Racks between 550 and 750 lb
Use 3/8" Nylon Rope

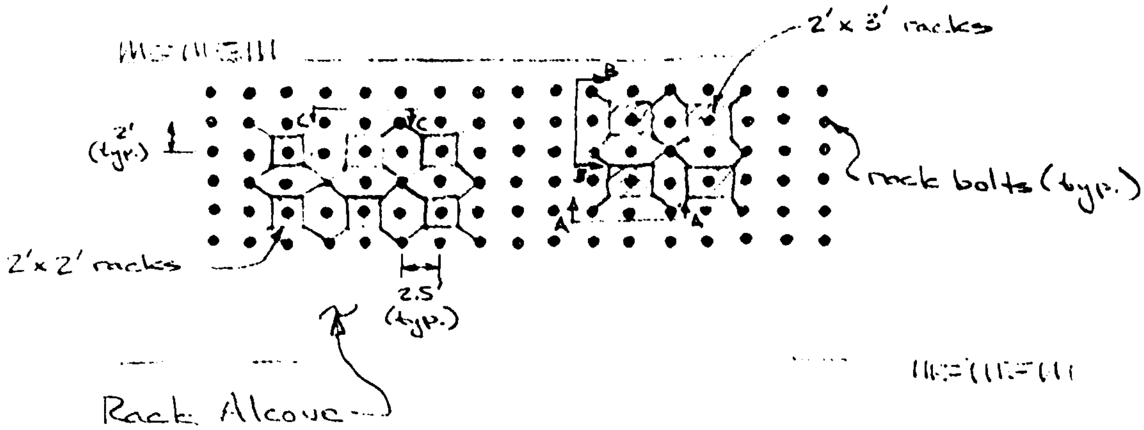
For Racks between 750 and 1150 lb
Use 1/2" Nylon Rope

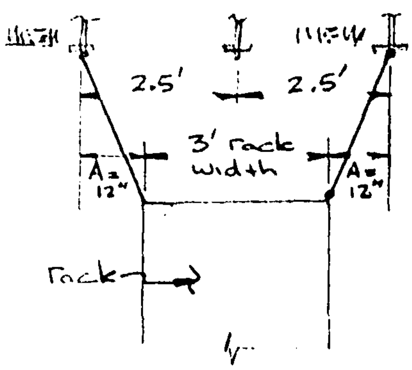
A = 11" to 18" B = 21" to 30"

EDAC

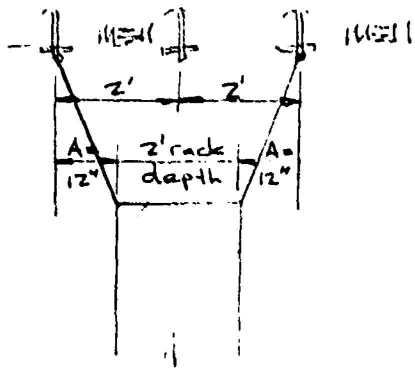
BY: [illegible] DATE: 3/6/77 PROJECT: DNA PAGE: 2 OF: 2
CHKD. BY: ______ DATE: ______ SUBJECT: [illegible] JOB NO.: 177-010

Location of Rock Bolts & Racks in Rack Alcove

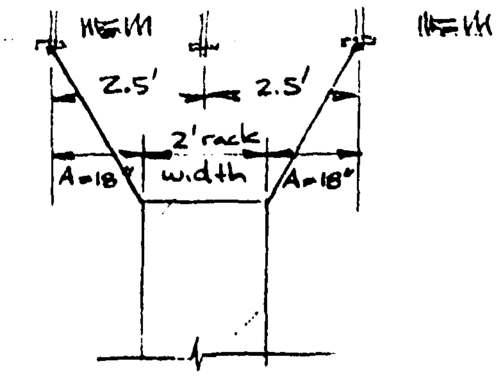




Section A-A



Section B-B



Note: "A" can be varied between 11" & 18" for rack widths between 2 and 3' such that the distance between supports is 5 feet.

Section C-C

EDAC

177-040

MEMO

TO: Joe LaComb

March 19, 1979

FROM: R. P. Kennedy RPK

SUBJECT: Use of Positive Expanding and Shrinkage Compensating Concrete and Grout

---

We understand that it may not be possible to achieve the expansion for future concrete and grout mixtures as has been available in the past. In this memo, the usages where positive expansion or shrinkage compensation are either necessary or important are outlined. These comments are intended to serve as a guideline as to where the greatest efforts to achieve expansion should be made for future designs.

It should be noted that shrinkage compensation is very desirable for containment structures in any configuration. However, positive expansion and shrinkage compensation are less important for structures in which potential leak paths cross zones of compression caused by pressure loading. For example, in keyway type containment plugs, the potential leak path along the rock-concrete interface is blocked by the compression zone at the portal side of the key. On the other hand, for friction type containment plugs, the potential leak path at the rock-concrete interface behaves in shear or friction rather than compression. For friction type plugs, positive expansion is essential to assure reliable plug performance.

For steel trainways, passageways or crawlways in which grout is placed, there are always interior gas block rings which create a tortuous leak path as well as small zones of compression at the portal side of the rings under pressure loading. In our judgement, positive expansion is desirable but not essential for providing reliable containment when grout is placed within steel passageways. However, shrinkage compensation is essential for a reliable design in this application.

In summary, shrinkage compensation is desirable for all containment structure applications. Whether or not positive expansion or shrinkage compensation is essential in various applications for containment structures is summarized as follows:

Preceding page blank

Usage	Shrinkage Compensation	Positive Expansion
Keyway-type Containment Structure	Desirable but not essential	Not important
Friction-type Containment Structure	Essential	Essential
Placement within Steel Passageway or Crawlway with Interior Gas Block Rings	Essential	Desirable, but not essential

EDAC

177-040

MEMO

TO: Joe LaComb

DATE: March 19, 1979

FROM: R. P. Kennedy RPK

SUBJECT: Recommendations for Friction Tests

Post-shot photographs of styrofoam blocks used for shock mounting o instrumentation racks and Roses cubicals for DIABLO HAWK indicated that these blocks may not have slipped on the plexiglas sheets in the manner w would have expected from our analyses. Although the behavior of the shoc mounting for instrumentation racks and Roses cubicals was adequate for th DIABLO HAWK event, we believe that it would be desirable to conduct frict tests in order to better understand the slippage of the styrofoam blocks plexiglas sheets for future shock mounting designs.

Current practice is to mount a plywood base plate on the styrofoam block such that the slipping surfaces are plywood and plexiglas. We woul recommend that friction tests be performed in order to determine the stati and kinetic friction coefficients for plywood on plexiglas surfaces. In addition we would recommend that friction tests for other materials which might be considered for shock mounting designs in the future also be performed. Examples of materials for which static and kinetic friction coefficients should be determined are:

1) Plywood base plate on plexiglas sheet
2) Steel base plate on plexiglas sheet
3) Plexiglas base plate on plexiglas sheet
4) Teflon base plate on plexiglas sheet
5) Teflon base plate on teflon sheet
6) Plywood base plate on teflon sheet

For these tests, special care should be taken to simulate actual tunnel conditions at shot time for the materials considered. We suggest that these tests should even be performed in one of the tunnels.

cc: A. C. Hollins - H&N, Area 12

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